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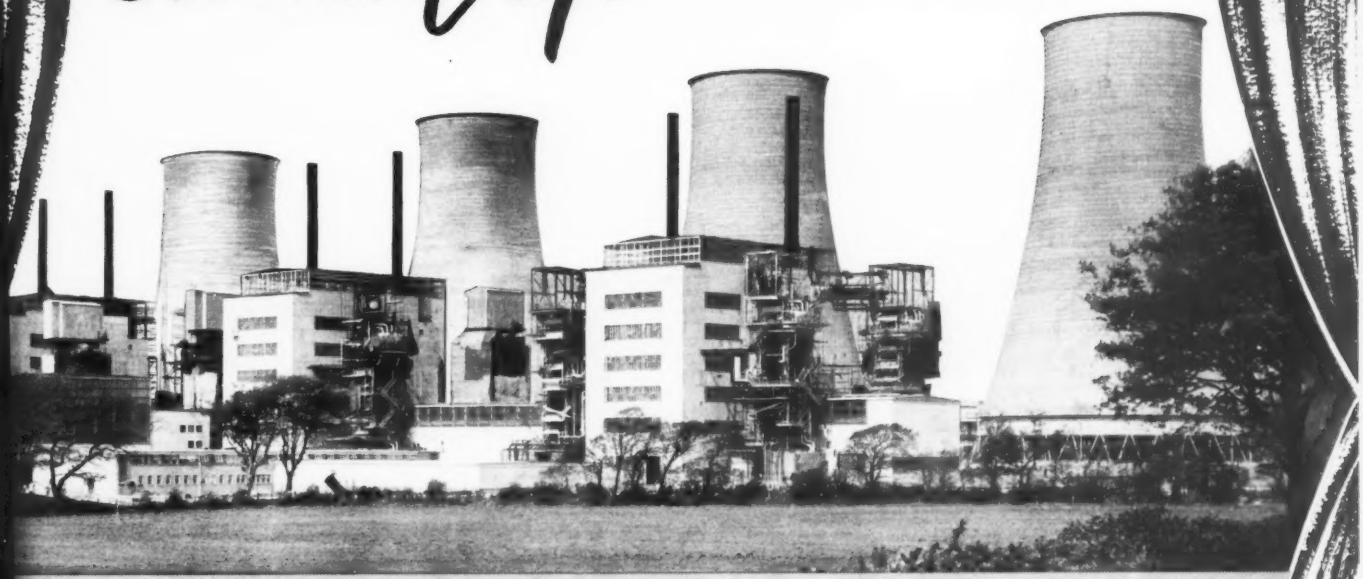

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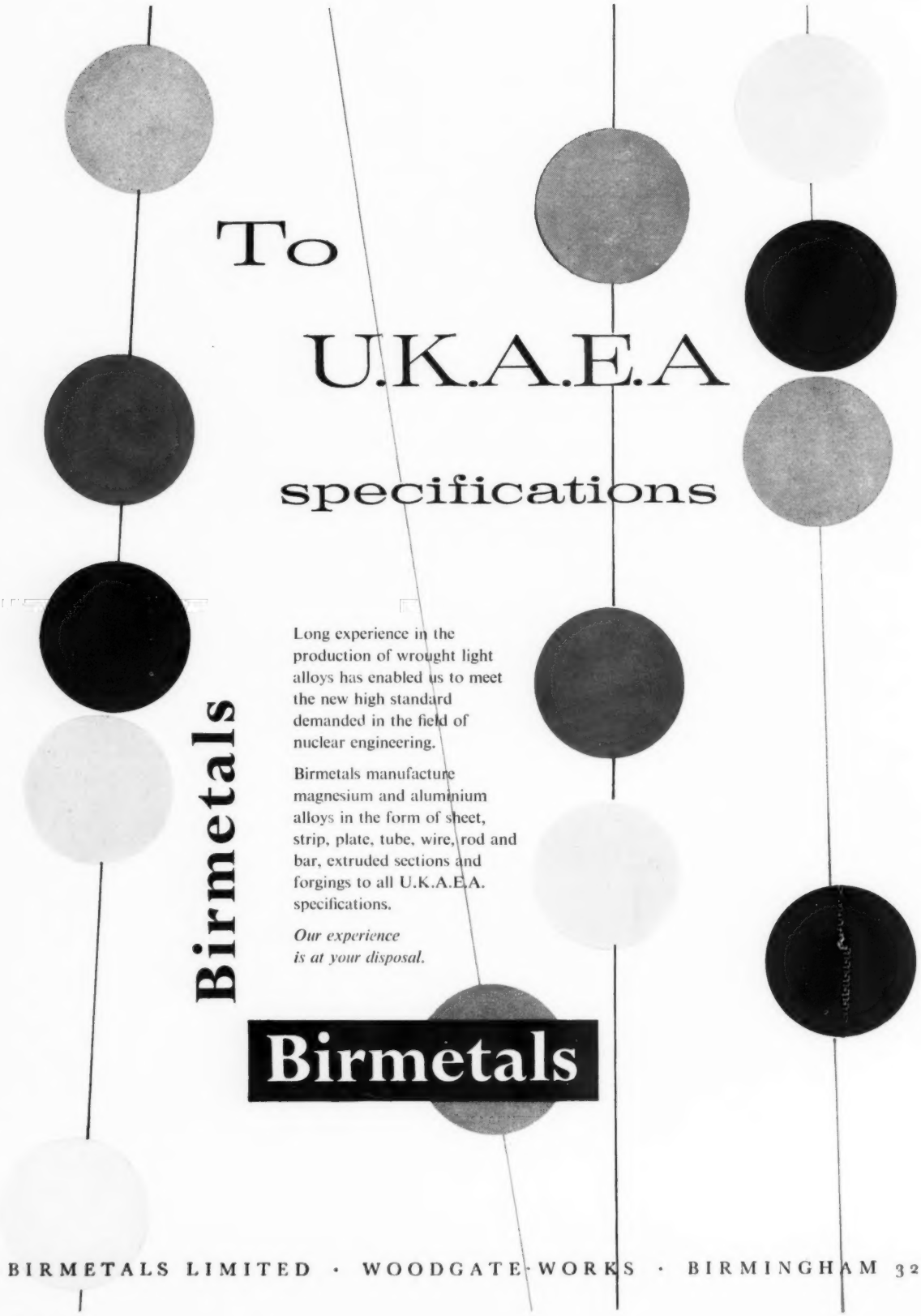

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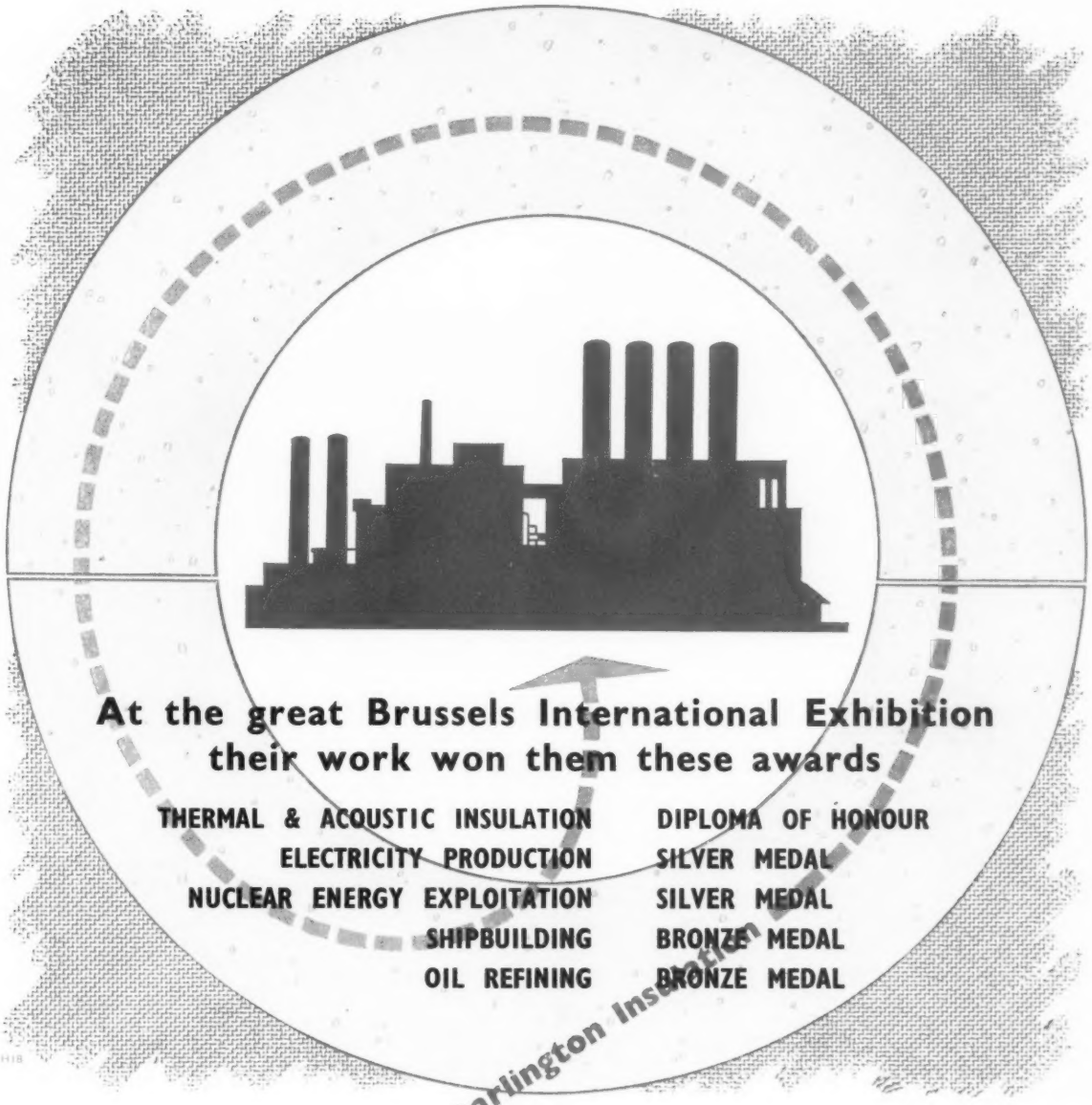

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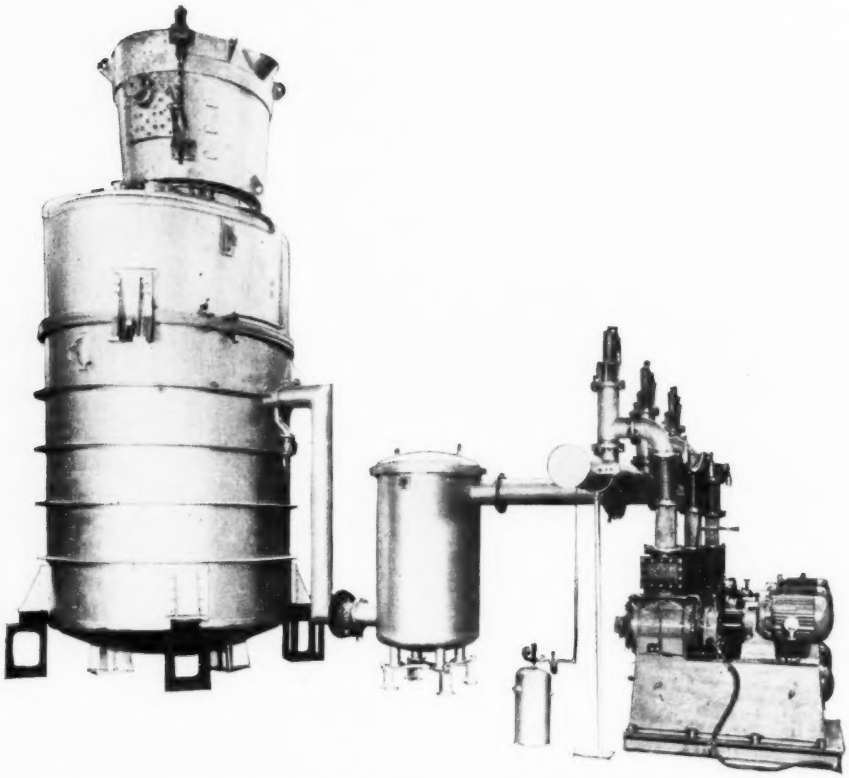

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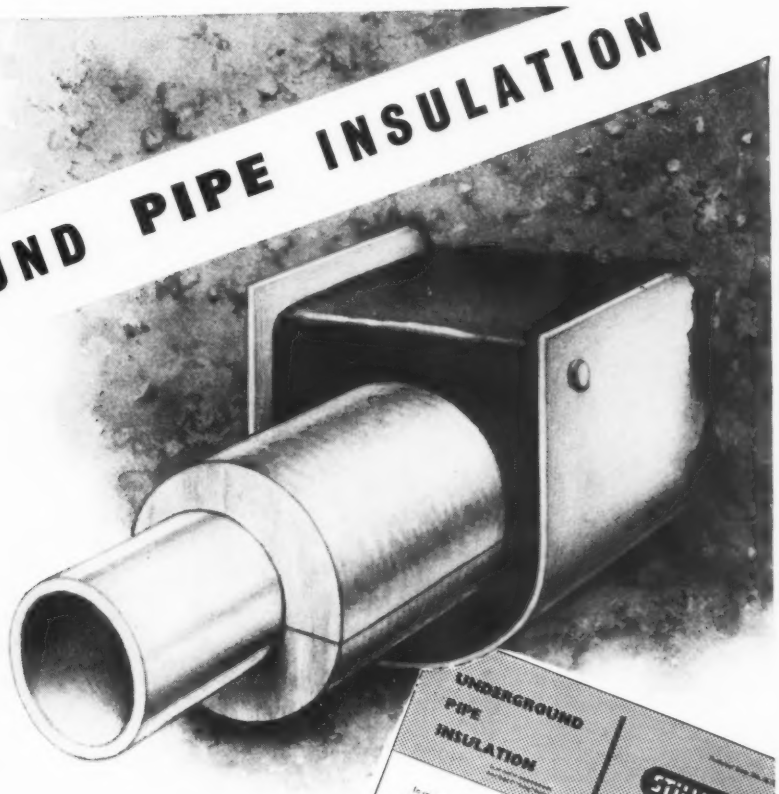

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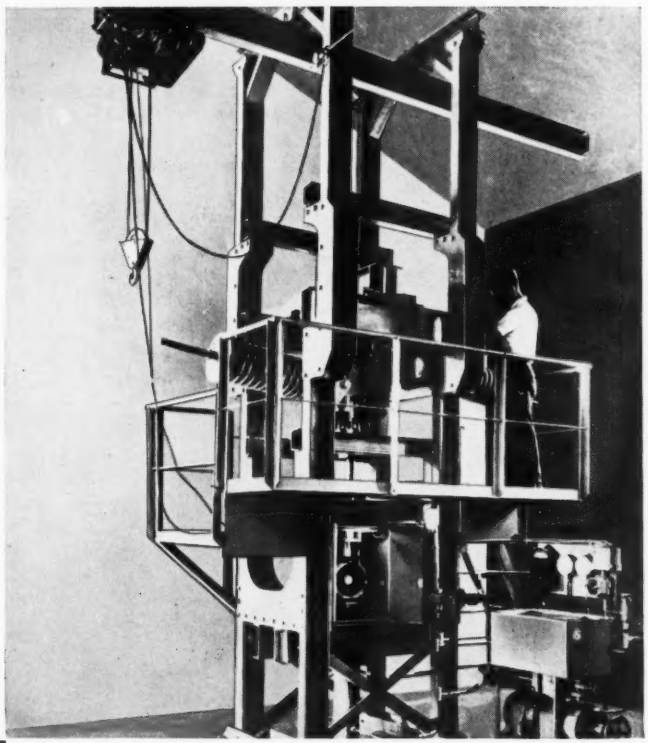

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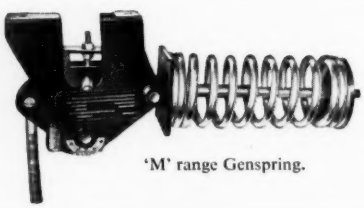

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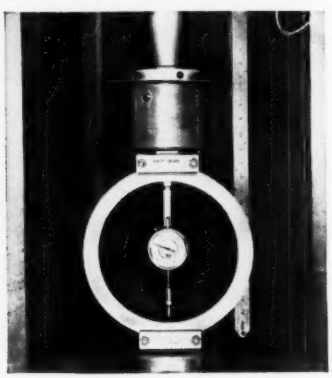

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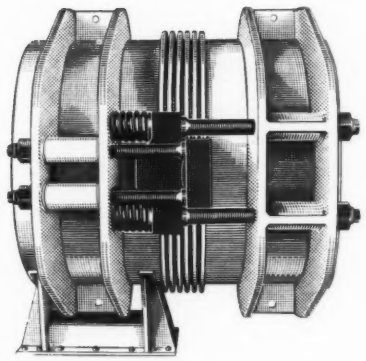

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Students at the Harwell Radioisotope School

RADIOISOTOPE TRAINING IN U.K.

THE large and increasing use of radioisotopes in all fields of industry, medicine and research has made it necessary to provide training in the practical applications and safe handling of radioisotopes and large radiographic and therapeutic sources. Initially all training in the United Kingdom was undertaken by the Isotope School of the Atomic Energy Research Establishment at Harwell, and this school has continuously increased both the scale and scope of its work.

Similar training is now given at many colleges. So far, although some aspects of radioactivity figure in the curricula of first degree courses and in the examination of the professional bodies such as the Royal Institute of Chemistry and the Institute of Physics, the practical use of radioisotopes is not normally part of the training of undergraduate students.

Radioisotope training is mainly at a post-graduate level. Several technical colleges have set up courses at technician level and upwards and a few schools have introduced a little radioisotope work into the curriculum of their senior pupils.

Training currently available can be divided into three categories: university courses and courses at hospitals and medical schools; full-time short courses, either general or specialized; and part-time courses.

Well established courses in specific subjects such as nuclear physics, radiation chemistry and nucleonic measuring instruments have for a number of years been available at practically all U.K. universities at a first degree level and quite a number of them also offer courses leading to higher degrees.

Radioisotope techniques form part of the training of students in most teaching hospitals. At St. Bartholomew's Hospital Medical School, for instance, a course on isotopes in biochemistry is taken as part of the London University MSc in biochemistry and at the Royal Marsden Hospital, London, a two-term course is given on radioisotopes in biology and medicine as part of the MSc in biophysics.

Full-time short courses are designed to give students background knowledge of the principles involving the use of radioisotopes and practical experience in their safe and effective utilization.

Several colleges of technology and technical colleges provide such courses, which are very often modelled on those given at the Harwell Isotope School. Established in 1951, this school has held over 50 four-week standard courses on radioisotopes which have been attended by over 100 students from both the United Kingdom and overseas. Its proximity to the Atomic Energy Research Establishment enables it to provide unique facilities—consultation with experts and work on short-lived radioisotopes being among these.

The school also provides full-time courses of a specialized nature such as autoradiography for biologists, autoradiography for metallurgists, isotopes in medicine, isotopes in engineering, courses for technical school teachers, courses for agricultural reconnaissance officers, and isotopes in industry for senior executives.

Part-time courses on radioisotopes are held at many technical colleges. The courses are of a varied type but generally include some practical work. In several cases research problems are undertaken.

HARWELL REACTOR SCHOOL

Britain's Premier Nuclear Training Centre

ALTHOUGH the facilities now provided at some United Kingdom universities and technical colleges for the training of nuclear engineers are excellent, none can quite match those at the Harwell Reactor School.

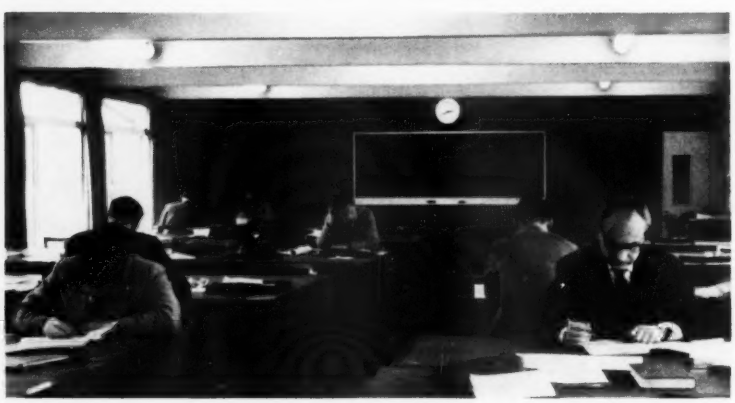
For one thing the students have access to critical reactors installed at the Harwell Atomic Energy Establishment, which the school adjoins, and for another they have the opportunity of meeting men who are actively engaged in leading nuclear research and development and discuss with them the problems of nuclear reactor technology—a facility not readily available elsewhere. Yet another advantage is the prestige attached to "having been to Harwell."

The purpose of the school, which was established in 1954, when Britain announced her nuclear power programme, is to qualify trained scientists and engineers for the task of designing and developing new reactor systems. Students, who have to be graduate physicists and engineers, are given a thorough grounding in reactor physics, chemistry and engineering, backed by an insight into such problems as reactor safety and radioactive effluent disposal. As might be expected, emphasis is placed on the graphite moderated gas-cooled reactor system but not entirely to the exclusion of other reactor types.

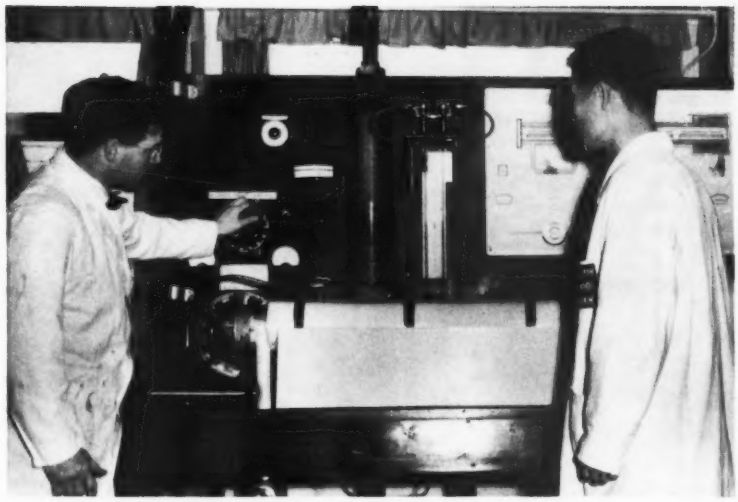
Much practical work is carried out, the school being equipped with various experimental rigs and apparatus. In addition, students carry out experiments on the AERE reactors GLEEP and BEPO.

The principal course, or standard course, as it is called, lasts for 16 weeks. The first six weeks are taken in one of three specially selected Colleges of Advanced Technology—those at Birmingham, Bradford and Salford, Manchester. Originally, when the course lasted for 14 weeks, all of it was taken at Harwell. There were two reasons for making use of the technical colleges. In the first instance, it was felt that because the colleges are very well equipped to give the elementary part of the course, the reactor school could be left to concentrate on the more advanced and more technological part of the course. Secondly, it was a means of spreading the teaching of nuclear engineering outside the Authority. As a result of reducing the time spent at the school, courses can if necessary overlap and so enable four instead of three to be run each year.

The school was originally housed in a hut (now a County Council



Ample accommodation is provided at the school for students to carry out private study. Illustration on the left shows part of the library, which contains a wide range of reference and text books on nuclear energy subjects as well as copies of current periodicals. The lower illustrations are views of the common room. The three students in the left hand illustration are Mr. B. E. Hart, from the UKAEA at Dounreay, Mr. D. Mangan, from Risley and Mr. N. D. Baines, from UKAEA Culceth Laboratories. On the extreme right of the right hand illustration is Mr. W. K. H. Blenke, from the Badische Anilin-unt-Soadafabrik AG, Ludwihgshaffen.



(*Above*) **Mr. H. Bowes, engineering demonstrator (*left*), explains a heat transfer experiment to Mr. C. S. Choi, of the Atomic Energy Commission of Korea. (*Top right*) Mr. G. A. Holder, physics demonstrator (*right*) explains a sub-critical assembly to Mr. C. J. Kim, of the Korea Electric Power Co. (*Lower right*) Mr. H. W. Glauner, of Kernreaktor, Karlsruhe, W. Germany, at the reactor simulator. Mr. R. G. Davis, simulator demonstrator, looks on**

nursery) in which there was accommodation for 35. When the school was moved in 1956 into its present attractive home the number of available standard course places rose to 60.

The present school, opened by Sir John Cockcroft in September, 1956, is a single-storey U-shaped building tastefully decorated inside and out. One limb of the " U " houses a large common room where students can carry out private study. It is also sometimes used as a lecture room. The other limb houses the administrative offices, principal's study and a library. The laboratory where all the school equipment is housed and the practical work takes place, together with a lecture room and lounge, make up the connection between the limbs.

Overseas Students

The standard course since it was introduced in 1954 has been taken by 858 students, over a third of whom have come from overseas countries. They have represented over 40 nationalities and have included Australians, Koreans, Peruvians, Egyptians, Yugoslavians and New Zealanders. Germany has sent the largest number of students (57), and Japan the second largest (25).

Students have to be of graduate standard and are mainly physicists or engineers and if from overseas they have to be sponsored either by the nuclear energy commission of their country or a suitable industrial organization. Of the United Kingdom students that have passed through the school, incidentally, one-third have been sponsored by the UKAEA and the rest by industry and the CEGB.

In the early part of the course allowances are made for students' previous training and experience. There are, for instance, lectures on basic nuclear physics for engineers who have not had training in this subject. Likewise, there are lectures on fluid flow, principles of heat transfer and thermodynamics for physicists who have not had experience in the problems of extracting heat from power plants.

All students attend lectures on reactor theory and reactor engineering. The first of these subjects deals with reactor criticality, control rod calculations and reactor reactivity. The reactor physics lectures deal with biological shields, exponential and critical experiments and fuel cycles.

Engineering Lectures

In the engineering lectures the students learn how to calculate heat transfer rates, temperature distributions in reactors, thermal stresses and the pumping required to circulate the coolant. The kinetic behaviour of a reactor is considered and the various ways in which a reactor can be controlled are discussed. Lectures given on the instrumentation of reactors besides covering the measurement of power levels, deal also with the mechanisms for shutting down a reactor and burst cartridge detection methods.

Some of the more specialized nuclear engineering techniques such as the design of electro-magnetic pumps for circulating liquid metal coolants are also explained. This group of lectures concludes with descriptions of the various possible types of power reactors.

The chemistry and chemical engineering lectures describe the manufacture of pure moderators and fuels; systems for processing irradiated fuel elements to extract fission products and the fissile material which is bred are also studied. The metallurgy lectures make clear to students the properties of uranium, thorium, plutonium and other metals used in reactors, the fabrication of fuel elements and their behaviour under irradiation. Special topics such as the corrosion of fuel-element cartridges by coolants are also dealt with.

Health physics lectures describe the measurement and control of radiation dosages received by reactor operators and the important subjects

of reactor safety and radioactive effluent disposal are thoroughly examined.

Lectures are given on Mondays, Wednesdays and Fridays, the other days being devoted to experimental work. Three lectures are given in the morning and one in the afternoon of each lecture day; the remaining time is spent in private study or in informal discussions with lecturers.

To reinforce the lectures there are classroom periods when the students are shown how to solve particular problems and during the course the students work methodically through the design of a graphite-moderated gas-cooled power reactor.

Lectures are given by the school staff and research workers from the various AERE Divisions. Other lecturers come from outside and each of the consortia currently building a nuclear power station sends a lecturer to describe their particular project and the various problems involved.

Mr. J. F. Hill, BSc, Principal of the school

Mr. R. M. Nelken, of the Palestine Electric Corporation, signs in the visitors' book in the entrance vestibule of the school

The Apparatus

For practical work the school is equipped with sub-critical assembly, graphite stack, three heat transfer rigs, a reactor simulator and a small chemistry laboratory. Experiments carried out by the students include the determination of slowing-down length of fast neutrons and the diffusion lengths of thermal neutrons on graphite and, with the sub-critical assembly, the calculations of critical sizes. The simulator is used for the study of various problems in reactor kinetics, while in the chemistry laboratory a simple chemical extraction experiment is carried out. Although the chemicals used in this laboratory are relatively harmless, students have to change into protective clothing and take precautions similar to those they would take in a " hot " laboratory. It is considered good training for them.

With GLEEP and BEPO in the AERE, students determine neutron absorption cross sections, study shielding problems, measure neutron flux distributions, operate a liquid metal rig, and determine the effect on the reactivity of BEPO of inserting an absorber at various positions within the reactor. They also take part in running BEPO from a cold " unpoisoned " condition to full power. Practical work is carried out under the supervision of a team of demonstrators.

Visits are made to the chemistry and chemical engineering divisions of the AERE, where the students examine, among other things, a plant for extracting uranium-233 from thorium. They are shown a low powered heavy water moderated reactor DIMPLE, and the high flux research reactor DIDO.

During the middle of the course a visit is made to one of the nuclear power stations under construction for the Central Electricity Generating Board.

A Weakness

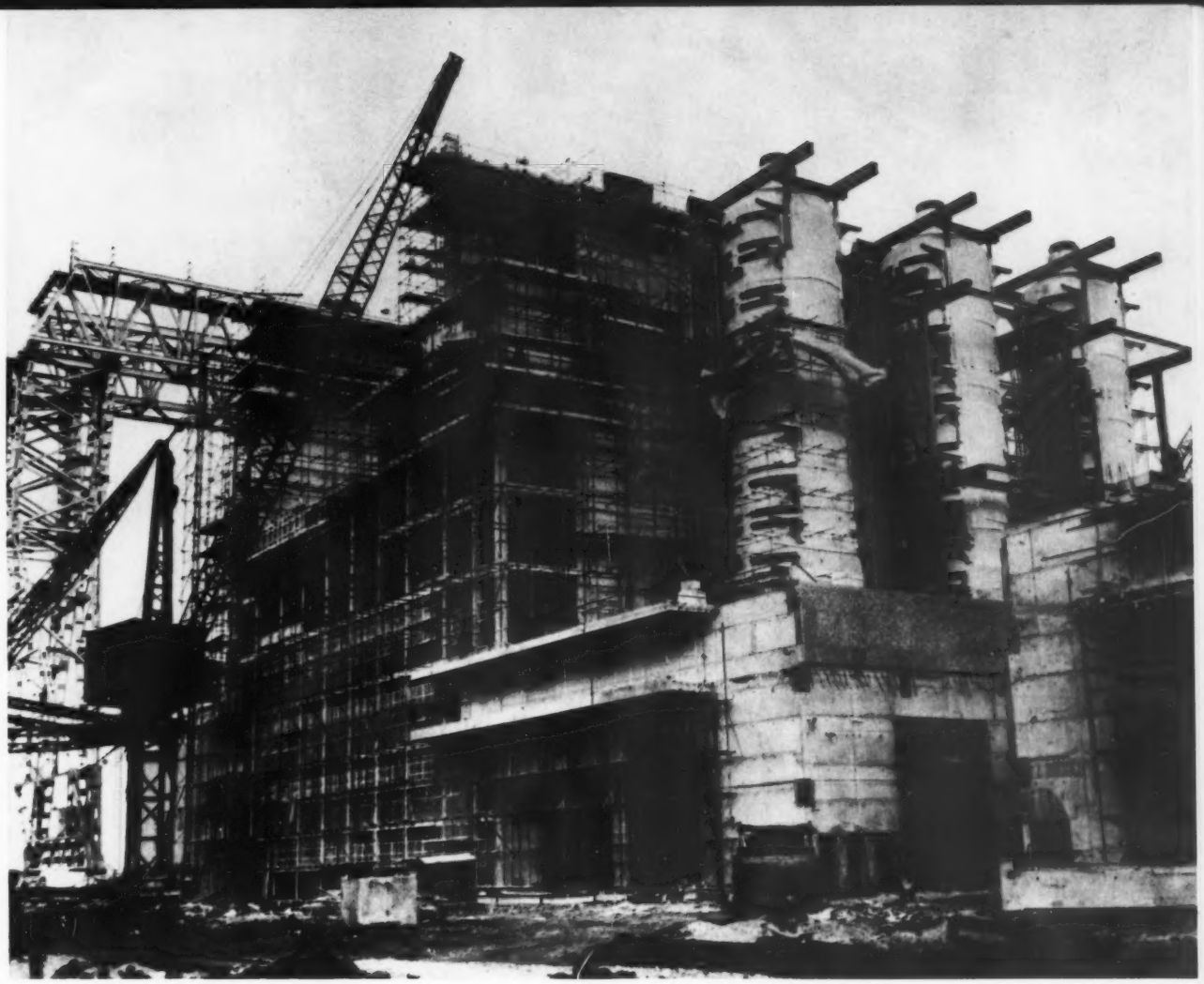
There are no examinations attached to the course and, therefore, no academically recognized diplomas or certificates can be awarded. This is perhaps the chief disadvantage of the school as it means there is no way of proving whether or not a student has benefited from the course. A close watch is made of the students' progress, however, and their note books are carefully scrutinized from time to time.

As well as the standard course, the school organizes other, shorter courses. Of these the best-known and most popular is the Senior Technical Executives' Course. This lasts for two weeks and is a " familiarization " course for senior industrialists who have a technical background. A few lectures are given on fundamental principles and the rest are of a general nature dealing with different aspects of nuclear energy.

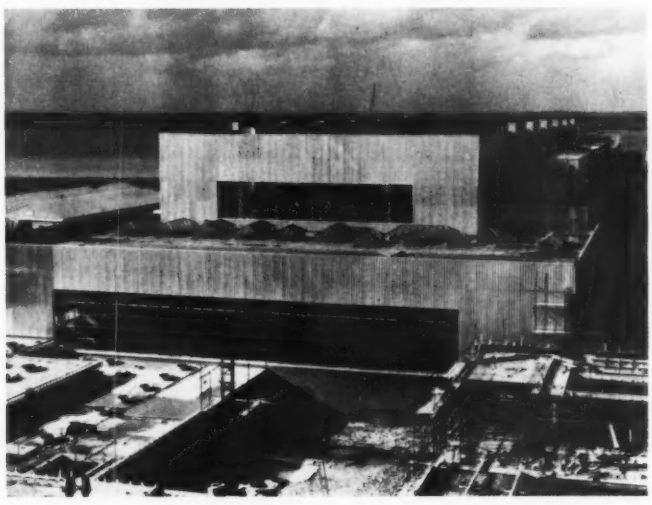
Most of the lecturers for the STE course, as it is called, are given by senior staff members of the AERE. In addition there are visits to various AERE divisions and to one of the nuclear power station sites.

Other short courses are held at the school from time to time according to demand, among them being 10-day intensive courses for teachers in universities and higher technical colleges in OEEC countries, and 10-day courses on control and instrumentation of reactors.

During the few years it has been in existence the Harwell Reactor School has played a leading part in the dissemination of practical knowledge in nuclear subjects and until recently the only nuclear training centre in the United Kingdom. With some universities and technical colleges having introduced courses on nuclear technology into their curricula, there will be less dependence on Harwell for the training of nuclear technologists and engineers. Nobody would deny, however, that the regard and esteem in which the school is held will remain undiminished.



Progress at **BRADWELL**



(*Top*) **No. 1 reactor building with insulated boilers in place. All six boilers to the reactor are erected and tubing is well under way. The Goliath crane can be seen in the background.** (*Centre right*) **Interior of No. 2 reactor showing supports for the reactor pressure vessel and the CO_2 duct openings.** (*Bottom left*) **The turbine hall. All the cladding and glazing is complete. To the right can be seen the surge tanks, while on the left part of the workshops and stores are visible**

Construction of Active Ancillary Buildings

PART I

by W. A. Gillingham, MRSH, AIPME

The author, who is in the reactor department of W. S. Atkins and Partners, the Consulting Engineers, examines the secondary sources of radioactivity in a nuclear power station and describes how they are to be dealt with at Berkeley. The article is based on a lecture recently delivered by the author at the South East London Technical College

THE active ancillary buildings of a nuclear power station are those parts of the station associated with fuel storage and treatment, reactor maintenance and health physics. Also included are the facilities for dealing with protective clothing. In all these buildings a certain amount of radioactive contamination occurs and they have therefore to be designed and controlled in such a way as to enable this contamination to be kept to a minimum.

Before dealing with the construction of these buildings it will be useful to consider the possible sources of radioactive contamination. Broadly, these can be divided into three groups: solids, liquids and gases.

Items that can be classified as " solids " are as follows:—

(*a*) Articles used in the reactor and laboratory and elsewhere, such as hand tools, beakers, gloves, etc. Vacuum cleaner parts, filter papers. Graphite struts, broken control gear, etc.

(*b*) Clothing (overalls and fully protective clothing).

(*c*) Equipment requiring removal from the pipe circuits, items of plant, monitoring equipment, scrub brushes and rubbish. Shields and swabs from monitoring routines.

To Scrap Heap

Equipment under the last heading may be destined for repair and replacement, therefore requiring decontamination, or it might be destined for off-site disposal to the scrap dealer or rubbish bin, in which case monitoring and sentencing has to be carried out. If it is destined for the scrap heap, rough treatment may be used in the decontamination process. In other instances activity may be reduced to a permissible off-site level by holding the item for a few days to bring about radioactive decay.

Expended fuel elements and fractured or burst fuel elements can also come under the classification of " solid " radioactive sources.

Liquid Wastes

Radioactivity in liquids arises from:—

(*a*) personnel ablutions;
(*b*) clothes decontamination in the laundry;
(*c*) the decontamination block or spaces;
(*d*) the fuel cooling pond;
(*e*) the treatment plant for cooling pond water;
(*f*) the fuel discharge tunnel and sump;
(*g*) the charge face maintenance bay;
(*h*) the treatment plant.

Gaseous contamination occurs in the:—

(*a*) air cooling systems around the reactor pile;
(*b*) maintenance bay ventilating extract;
(*c*) fume hoods extract, etc.; and
(*d*) cooling pond ventilations systems.

The design of the buildings have to take the problems arising from these various sources into account. Sometimes the necessity to perform one operation brings with it an attendant problem resulting in the necessity to build a so-called active ancillary. For instance, protective clothing, when it becomes contaminated, requires monitoring to determine its state, and laundering to remove any contamination. The laundry produces an effluent which may require treatment making it necessary to install equipment or produce a method to enable its safe discharge from the site.

The active ancillary buildings of a power station include:—

Health physics laboratory, main change room, laundry (active), sub change rooms, the fuel store, reactor maintenance bay, reactor discharge chute tunnel sump, reactor subchange, cooling pond-washdown bay, cooling pond-closed cycle coffin wash, and cooling pond " polishing " and desludging plant, decontamination building, treatment plant and solid disposal mortuary.

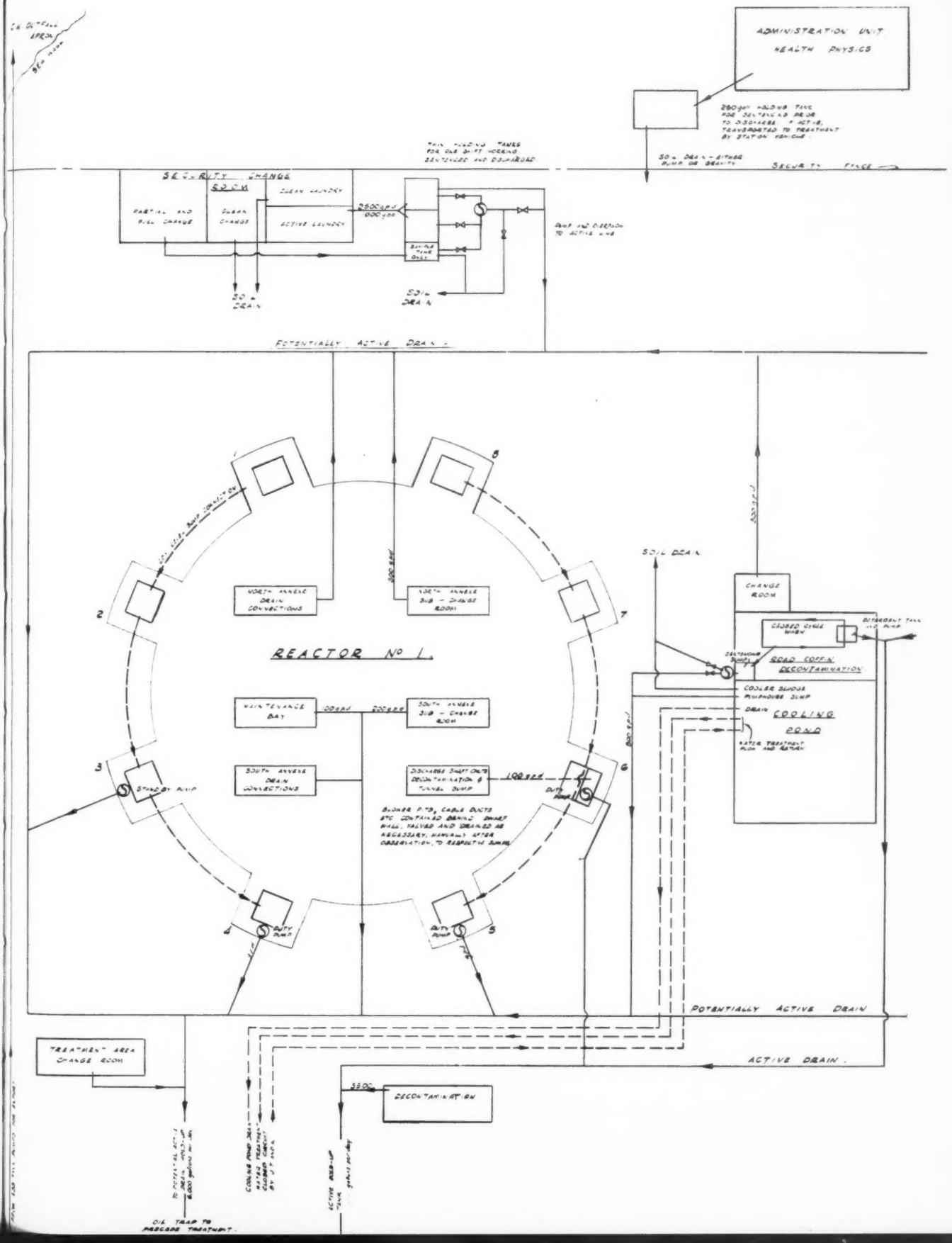
" Police " Duties

The health physics laboratory is established for the function of taking samples in and around the site, and analysing them to assess level of contamination of ground, air and liquid. Laboratory staff are responsible for monitoring and keeping health checks of personnel, keeping records and issuing of film badges. One could say from the radioactive point of view that they are the policemen of the station.

Because sampling and analysing is carried out, small quantities of low

(*Continued on page 252*)

(*Opposite*) **Diagram showing sources of radioactivity at Berkeley nuclear power station and routing of effluents. Sources from reactor No. 2 (not shown) are same as from No. 1**


ADMINISTRATION UNIT
HEALTH PHYSICS
SECURITY CHANGE
SECURITY FENCE
REACTOR No 1.
CHANGE ROOM
POTENTIALLY ACTIVE DRAIN
ACTIVE DRAIN.
DECONTAMINATION
TREATMENT AREA CHANGE ROOM
OIL TRAP TO PROCESS TREATMENT
STAND BY PUMP
DUTY PUMP
DUTY PUMP
DUTY PUMP
COOLING POND

level activity arise in all three forms mentioned.

The laboratory can probably be classed as a Grade " C " laboratory, as given in the Code of Practice*, with conventional laboratory benches and fume hoods, and a counting room for measurement. The benches should be strong enough to carry shielding and have non-absorbent tops, preferably with removable, disposable covers, such as polythene sheeting. Wall finishes should be non-absorbent and free from crevice and dust-catching areas. The fume hood should be fitted for induced draught discharging to atmosphere, the diffusion available making a filter unnecessary.

At the Berkeley power station the liquid waste (being small) is kept in containers inside the building, and sentenced as necessary to be discharged either into the active treatment tanks or to soil drain. This is because the unit is located outside the main reactor area, and it was inadvisable to route an " active " drain outside the reactor fence.

Change Room Divided

The main change room straddles the security fence and controls the main route into the reactor compound area. It is divided into:—

(*a*) Partial change—this is for persons entering the area but not proceeding to positive radioactive duties such as decontamination bay.

(*b*) Full change—for those proceeding to an area where full protective clothing is required.

In both cases there is the provision for lockers, monitoring of hands and person, ablutions and foot barrier.

(*c*) Associated tea rooms—located between the clean and active zone with the facilities for hand washing and monitoring. The canteen staff are able to enter and leave from the " clean " side.

There is also a medical bay situated in this unit. This contains in addition to the normal first-aid facilities:—

(*a*) a sluice tray and slab with a hand spray;
(*b*) shower unit;
(*c*) monitor check; and
(*d*) easy access from both sides of the fence.

It should also have bins or bags for containing the clothes of injured people if it is necessary to discard the clothes. In my opinion it would also be a good thing to have a protective coverall available so that the injured person's clothes do not contaminate the unit.

The sub-change rooms are similar in function and description to the main change room except that they are located in a specific area such as the reactor charge face and decontamination building. There are no lockers and they mainly serve as a primary ablution and toilet facility for the workers in the area. They can also be used as emergency change rooms when necessary.

Straddling the security fence is the fuel store and fresh fuel is transferred from transport without operatives having to enter the controlled zone. Capacity of the store is equivalent to a $1\frac{1}{4}$ reactor fuel load.

The building requires to be dry and dust free and there should be a facility for loading the fuel truck for delivery to the reactor charge face.

The health physics laboratory, change rooms, medical bay and fuel store have few special building construction requirements. The most important feature is that the walls and floors should be finished so as to be impervious and easily decontaminable by washing or vacuum cleaner. Where constant decontamination is anticipated (on walkways in the main change areas, for instance), the use of disposable non-absorbent covers is desirable.

How to Finish

Some recommended finishes are:—

(*a*) chlorinated rubber and strippable lacquers;
(*b*) sealed concrete (only in very mildly contaminated areas);
(*c*) hard glossy painting, for surfaces in inaccessible areas, passages, etc.;
(*d*) epoxy-resin based paints. These have a better radiation resistance than chlorinated rubber, but curing is necessary which limits their application, especially on concrete areas; and
(*e*) vitrified tile for floor finishes with jointing selected for its decontaminable qualities.

Lockers should have enamelled finishes, inside and out, and it is advisable to use stoneware basins that are not subject to crazing. Floor channels should be used, where possible, in preference to buried drain pipes to enable leg wastes to be used for easy decontamination and maintenance. Woodwork should not be exposed to contamination and if it is necessary should be treated as expendable. A laundry is a necessary part of a nuclear power station as occupational coveralls cannot be sent to a public laundry. Very little contamination of such coveralls, however, is expected.

The Berkeley laundry building is divided into a clean, normal side, and an " active " side.

Laundry Procedure

The Code of Practice recommends that the clothing is sorted into sealed bags in order that decay of short-lived activity should take place. Care is required to avoid airborne activity being released from the dry clothing.

Typical treatment of contaminated clothes is as follows:—

(i) hot rinses;
(ii) hot solution of 3 per cent. citric acid which tends to produce a soluble citrate complex of the radioactive isotope;
(iii) further soapy and clear rinses;
(iv) hot solution 1.5 per cent. citric acid; and
(v) cold rinse.

The laundry is fitted out with spin and centrifugal type dryer and automatic washing machines. The ordinary industrial type is proposed for Berkeley.

After laundering the clothing is monitored and if necessary treatment repeated. Drying, pressing and storage is done on the clean side.

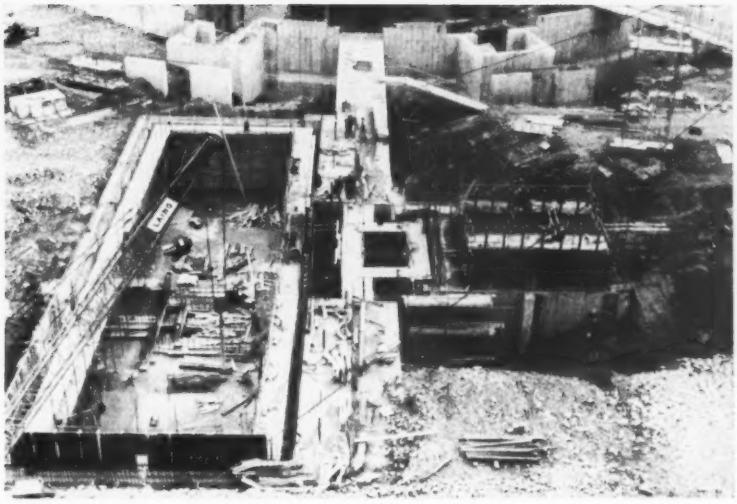
The effluent from the laundry machines and fittings discharge via drainage channels into a holding tank, where sampling and sentencing can take place. As for the other units the notable special construction requirements are the floor and wall finishes, decontaminable surfaces and separate effluent carriage systems.

The aim in the design should be to ensure segregation of the clean and active side by means of hatchways.

Most important ancillary of the nuclear power station are the cooling ponds. They function purely to hold irradiated fuel elements taken from the reactor pile, to enable them to cool and the short-lived activity from the mixed fission products to decay over 100 days.

The transfer from the pile is made by means of the special discharge machine via the discharge shaft and

* COP for protection of persons exposed to ionizing radiations.



Cooling pond at Berkeley. (*Above*) The foundations, showing channels used for checking radioactive leaks that might develop during construction and after. (*Right*) Six months later with walls of pond well under way

into a coffin mounted on a trolley, which has been previously winched into position in the tunnel. This has to be done remotely as the gamma radiation from the elements would be intolerable for any human to withstand and television is employed to facilitate the handling.

The coffin lid is closed and the trolley withdrawn along the tunnel to the cooling pond area. The coffin is then transferred into the pond of de-ionized water, which serves as a biological shield. The de-ionization of the water limits the impurities which would be subject to contamination. In addition, the pond water is maintained at a value of pH 11 in order to inhibit corrosion of the fuel element cans.

After initial decay and cooling, the fuel elements are removed and at the coffin transfer bay placed in containers for transfer to the Windscale processing plant.

Because the placing of the elements into the coffin is carried out under water the imported coffin is given a rinse in the washdown bay to remove road dirt, etc., before immersion in the cooling pond. After removal from the pond the coffin is transferred to the transfer bay and given a closed cycle wash by a detergent SDG3 (solution decontaminant general).

This is designed to remove contamination and the detergent is then rinsed off in the washdown bay. The rinse in this case emptying to a sump where monitoring and sentencing may be carried out. Periodically the SDG3 may need to be discarded and arrangements are made to send this to the active drains.

As the cooling ponds are a water containing structure, and more than that, possible containers of radioactive liquid, it was essential that any leakage from the ponds into the ground could be detected after the construction stage and the fault remedied. Detector channels were therefore constructed at the vulnerable places such as construction joints.

Sumps are Checked

These horizontal tell-tale drains end in a small sump at the walls and a vertical shaft or pipe will be incorporated into the wall so that checks can be made to determine whether the sumps are contaminated. Activity level will then give an indication as to leakage occurring in the pond structure. Areas where loads and rough handling is expected should be covered with suitable tiling or engineering brick jointed with a suitable material that can be easily decontaminated.

The recommended internal finish at Berkeley for the pond walls is four-coat chlorinated rubber. For the floor, which is required to withstand abrasion from the metal skips and corrosion from the caustic additive, 1 in. dense tile and resistant cement has been recommended.

On a structure such as the cooling ponds it is my opinion that a coating with perhaps a three-year life, easily removed, and economical in construction and maintenance is a safer proposition than an expensive lining that may be thought to last the life of the station. A semi-permanent lining can be useful especially where settlement cracks may be expected.

The ponds are housed to prevent dust, leaves and rubbish from entering them.

In order to facilitate underwater handling the surface must be reflection free and illuminated by underwater lamps.

Air Kept Sweet

Extract ventilation is provided through normal filters to keep the air sweet and to conduct the steam away over the handling portion, where coffins enter the pool. In order to keep the water free from impurities, an overflow is constructed which allows the pool to be circulated through a treatment plant. Losses are made up by a feed from the main make-up plant serving the station. This polishing unit is housed together with the active effluent treatment plant, and is dealt with under that heading. Provision is also made for the pools to be drained and the bottom cleaned up if necessary.

(*To be continued*)

Acknowledgements are made to the chief project engineer of the Central Electricity Generating Board, the chief engineer of AEI-John Thompson Nuclear Energy Co., Ltd., the principal of the South East London Technical College and to the Consulting Engineers, W. S. Atkins and Partners, for permission to publish this article. Photographs are supplied by John Laing and Sons Ltd.

APL blower oil on s

sentry-go at Bradwell...

The crucial points of the high pressure CO_2 coolant circuit at Bradwell will be the blower shaft seals. Every minute of every working day Shell APL blower oil will guard these escape points—being continually pumped into the seals and bearings, led away, purified and recirculated.

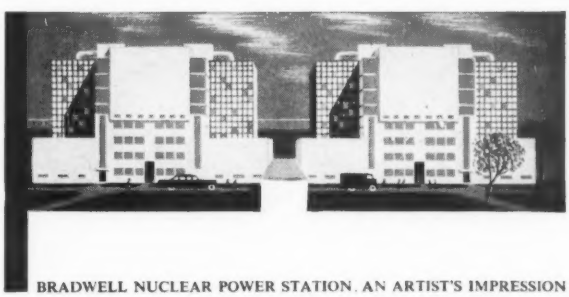
This very remarkable oil presents a two-way seal. Outwards, there is a minimum CO_2 loss as the oil has the lowest possible gas solubility. Inwards, in spite of the heat of the gas, oil vapour contamination is negligible thanks to the extremely low vapour pressure of the oil.

The research that went into APL blower oil is characteristic of the way Shell set about doing things. It was conducted at Shell's Research Centre at Thornton in close collaboration with the U.K. A.E.A. and the blower manufacturers. In the course of much fundamental research, a wide range of oils was subjected to vapour pressure and gas solubility tests in the laboratory. Selected oils from this range were used in the bearings and seals of a blower rig. In 1956, after four years of research, the finished product joined the Shell Atomic Power Lubricants range—marketed under the name of Shell APL 729. This oil has been in use at Calder Hall since the autumn of 1956.

The moral of the story is that Shell research is supremely applicational. The Centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right oil for the job. If you and your organisation have any major lubrication problem it pays to get in touch with your local distributor of Shell Industrial Lubricants.

The Research Story

Though the sealing action demanded of Shell blower oil is common in other industrial equipment such as hydrogen-cooled alternators, there were quite a few additional problems. It was necessary for the oil to have long life, low vapour pressure, low gas solubility, good thermal stability and high film strength —to be able to withstand high temperatures and to be resistant to all kinds of corrosive influences, including carbonic acid. The crux of the research was to combine all the above requirements into one oil, in order to minimise back diffusion of molecules which would contaminate the reactor.



BRADWELL NUCLEAR POWER STATION. AN ARTIST'S IMPRESSION

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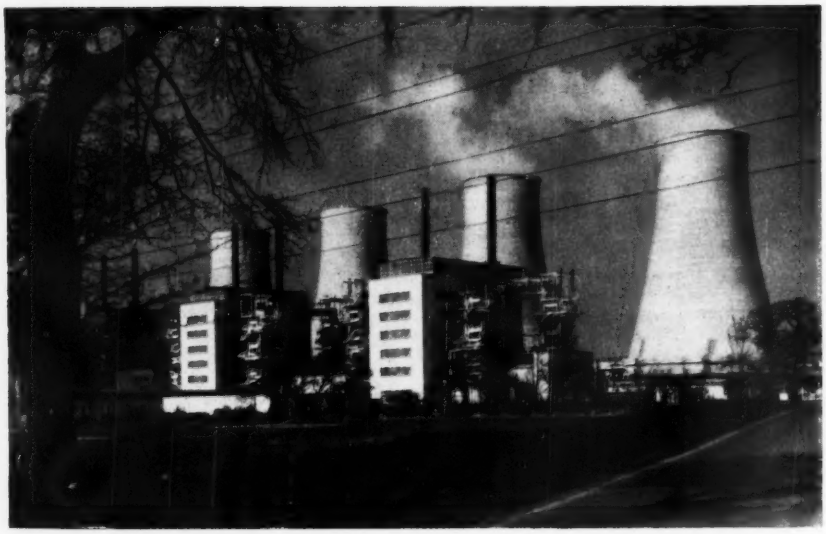


An immediately noticeable difference between Chapelcross and Calder Hall is the positioning of the cooling towers. At Calder they are placed in pairs in line with the reactors

Britain's second nuclear power/plutonium production plant was officially opened on May 2nd, by the Lord Lieutenant of Dumfriesshire. This article describes some of the design and construction features of the plant

CHAPELCROSS

How it differs from Calder Hall

by T. C. LEADER, BA

THE Chapelcross Works of the UKAEA is about three miles north-east of Annan, Dumfriesshire, and when complete will contain four 180 MW (heat) gas-cooled, graphite moderated reactors of the Calder design, and eight 23 MW turbo-alternators. The primary purpose of the works is the production of plutonium, but it will also have a net electrical output of about 140 MW.

When, in February, 1955, the Industrial Group was urgently required to increase plutonium production, the construction of Calder Hall as a two reactor station was in progress. It seemed that plutonium demands could be met most quickly by reactors of the Calder design, and it was decided to build six more such reactors although it was clear that no more than two of these could be accommodated at Calder. A new site had to be sought for the remaining four, which had to satisfy the usual requirements for nuclear installations and be within easy reach of Windscale where the fuel elements would be processed after irradiation.

Forty-eight possible sites were investigated in northern England and South-West Scotland, and the site near Annan was chosen in May, 1955. The site was a disused airfield, and was immediately available. Foundation conditions appeared suitable, with rock reasonably close to the surface, and although it was some way from the Solway there was sufficient water available from the river Annan to supply a cooling-water installation.

Appointed UKAEA Agents

In the interests of speed the Authority decided not to undertake any new design of the Chapelcross reactors except as demanded by site conditions and operational experience at Calder, when that became available. Rather than recruit new staff they appointed Merz and McLellan, the Consulting Engineers, as consultants for the power plant layout, services and civil engineering, and as construction agents for the whole station. This arrangement required only a small group at Risley to assume control of the project. A number of Merz and McLellan's staff who had been resident engineers at various conventional generating stations were transferred to Calder, where they acquired experience in construction aspects peculiar to nuclear reactors, and later went on to form the nucleus of the site staff at Chapelcross.

Chapelcross had an advantage over Calder in that it was planned as a four-reactor station from the beginning, and it was therefore possible to effect certain improvements in layout. The plan adopted is illustrated in Fig. 1. The site is large and the station was placed in the southern corner where access was provided by existing roads and a main concrete runway provided an axial road and hard-standing within the site. A major factor determining the layout was convenience of access for construction, but the architectural grouping of the buildings was agreed between the Authority's chief architect and the Dumfries Planning Committee.

The four reactors form a line of two semi-detached pairs parallel to the main runway and on one side of it, and the four cooling towers are arranged symmetrically in a parallel line on the other side. At Calder the cooling towers are placed in pairs at each end of the line of reactors. The single turbine house is not in line with the reactors, as at Calder, but parallel to them to the south, that is on the opposite side to the cooling towers, with the electrical control block on its southern face. The administration block is still further to the south and workshops

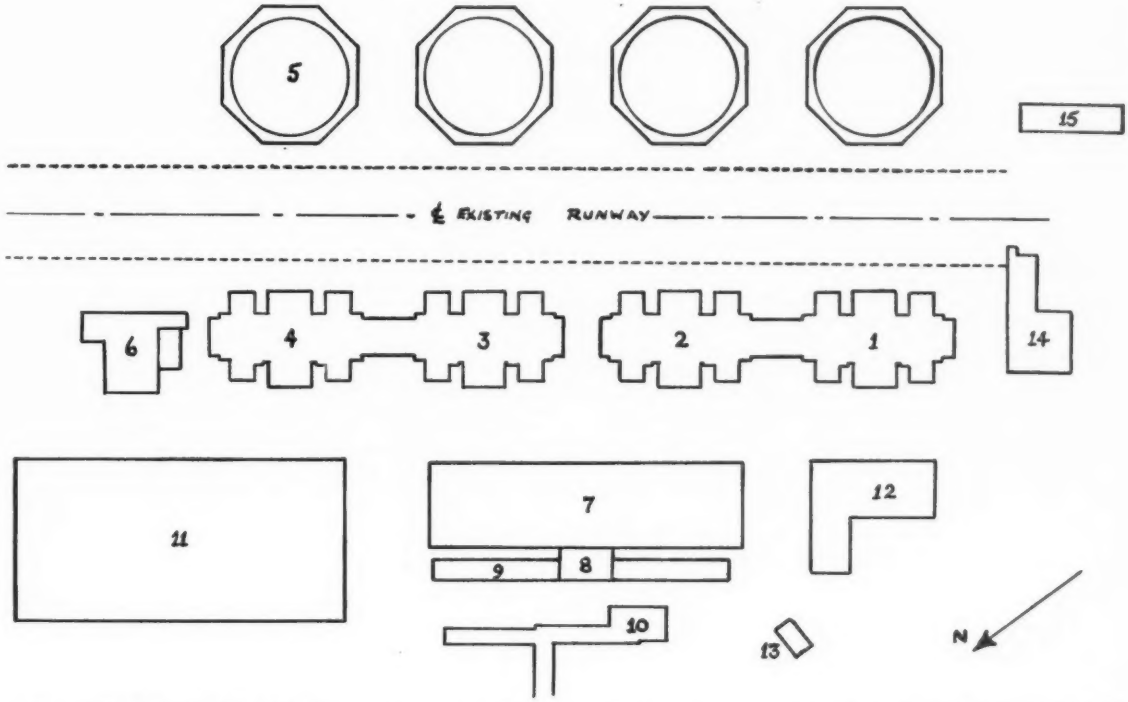


Fig. 1.—Plan of Chapelcross Works
Key:—1-4 Reactors; 5 Cooling tower; 6 Fuel element decay pond; 7 Turbine house; 8 Electrical control block; 9 Generator transformer compound; 10 Administration block; 11 SSEB 132 kV compound; 12 Workshops; 13 Police lodge; 14 Fuel element and general store; 15 Laboratory block.

are alongside the turbine house at its eastern end. The fuel element decay pond is in line with the reactors at one end and a fuel element store at the other.

Foundations Differ

The amount of redesign from Calder was a minimum, and the greatest differences between the reactor plant at Chapelcross and Calder are therefore in civil engineering, arising mainly from differences in foundation conditions.

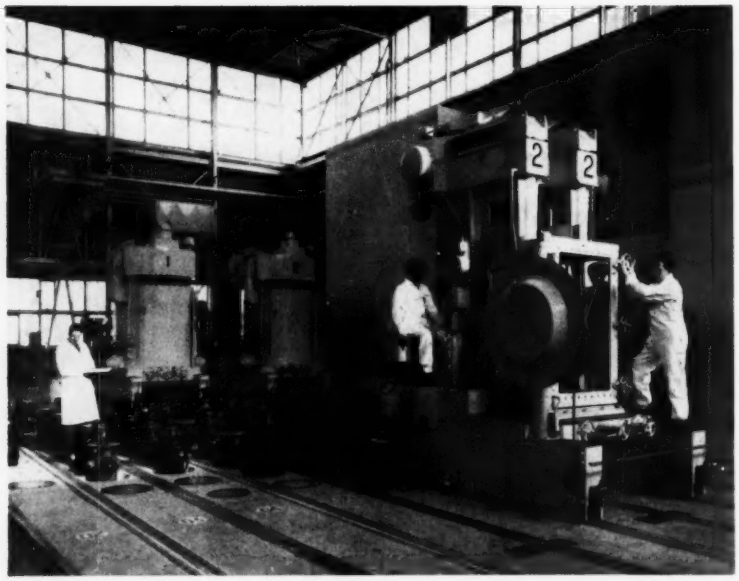
Sandstone with boulder clay above it lies at about 15-25 ft below reactors 1 and 2, at about 40 ft below reactor 3 and about 50 ft below reactor 4. The main coolant ductwork is designed on the basis of a maximum differential settlement of the reactor vessel relative to the heat exchangers of $\frac{1}{4}$ in. and at Calder, which is founded on moraine with only small clay inclusions, each reactor was founded on a very heavy raft with the heat exchangers and blowers on independent rafts alongside it. At Chapelcross the top surface of the sandstone was found to be very uneven and fractured and it was decided that the large quantity of clay prevented individual rafts from being acceptable, so that all foundations for reactors 1 to 3 were taken down to rock. In reactor 4 the reactors and heat exchangers were also founded on rock but the blowers were carried on beams supported from the heat exchanger foundations.

Other changes in the reactor buildings are small. Long blower houses are abutted in pairs, saving one gable end per reactor and two cranes.

Most of the component parts of the reactors are repeated as for Calder, and have been fully described elsewhere. There are slight changes in the design of the pressure vessels in way of the sampling pipe branches, aimed at reducing local stress concentrations, and minor design improvements in control rod mechanisms and supply systems. One major change has been the introduction of graphite sleeves into the moderator of reactors 2 to 4 in order to allow the moderator to run at a higher temperature and thus to inhibit the storage of Wigner energy. In reactor 1 the facilities for measuring fuel element and moderator temperatures have been extended somewhat and in reactors 2 to 4 they

MR. T. C. LEADER, BA, AMIMechE, who is in the reactor department of Merz and McLellan, the Consulting Engineers, was educated at Cambridge University where he graduated in the Mechanical Science Tripos in 1948. *Until* 1951 *he served a graduate apprenticeship with C. A. Parsons and Co., Ltd. He then joined Merz and McLellan and in* 1955 *was attached to the UKAEA for training. At the end of the year he went to the Calder Works and worked on the start-up and operation of Calder reactors Nos.* 1 *and* 2. *He returned to the reactor department of Merz and McLellan in Newcastle in September*, 1957.

The Author



The principal differences between Chapelcross and Calder Hall are to be found in the civil engineering. The reactors in both stations are identical in design and other aspects of the stations are in many cases identical. The reactors themselves for instance, are copies of each other, as are the charge and discharge machines (*seen above*) for loading and unloading the fuel elements

have been extended still further with the addition of a large number of extra thermocouples.

Decay Pond Necessary

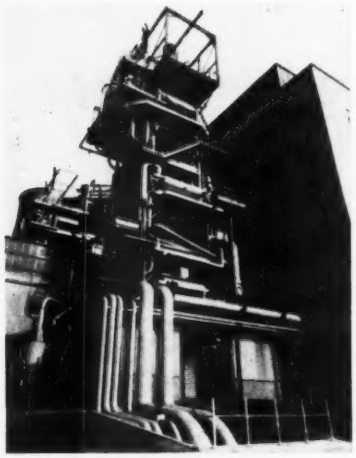
Carbon dioxide supplies to each reactor are metered, and a single storage plant, situated behind the turbine house, supplies all four reactors. Liquid carbon dioxide is stored in five 20 ton refrigerated tanks.

Calder, being close to Windscale, possesses no decay pond of its own but sends its irradiated fuel elements directly to the Windscale pond. At Chapelcross, however, a decay pond is necessary to accommodate the irradiated fuel until its activity has decayed sufficiently for it to be acceptable to the Windscale separation plant, and to permit its transport to Windscale in large batches without the use of disproportionately thick coffins.

The pond layout appears in Fig. 2. There are two similar half-ponds, each with a transfer and an exit bay at one end and what is known as a "burst" bay at the other. The depth of the water is 17 ft 9 in. and all handling of fuel elements takes place under water using extensive under-water lighting in the handling bays. The transfer and exit bays and their entrances are covered, but the remainder of the ponds and the burst bays are open. There is no connection between the two halves.

As at Calder, the reactor discharge machine lowers a basket of 24 irradiated fuel elements into a transit coffin on a bogie at the base of the discharge well. The bogie is hydraulically manipulated out of the discharge well, towed to the pond by a diesel locomotive and reversed into the transit coffin loading bay. The coffin-handling crane lifts the coffin into the transfer bay of either half pond and removes its lid, a hydraulic hoist removes the basket, and the coffin-handling crane returns the coffin to one of two decontamination vats and thence to a bogie for return to the reactor.

The fuel elements are dislodged from the basket by operators using long tongs, and, when the basket is taken away fall to the pond floor. The basket is removed by the basket handling crane, decontaminated and returned to the reactor by van, and the fuel elements are lifted by tongs into a skip. Skips are rectangular open-topped containers,



One of the heat exchangers on No. 1 reactor at Chapelcross

3 ft 10 in. long by 2 ft 8 in. wide and 3 ft 7 in. deep, of painted mild steel each designed to hold about 140 elements. They are handled by two skip-handling machines, and there are 210 skip-storage spaces with provision for double-stacking if necessary. The machines may be

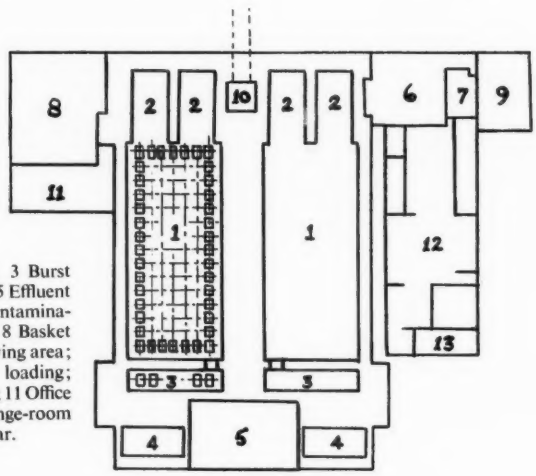


Fig. 2.—Plan of fuel element decay pond

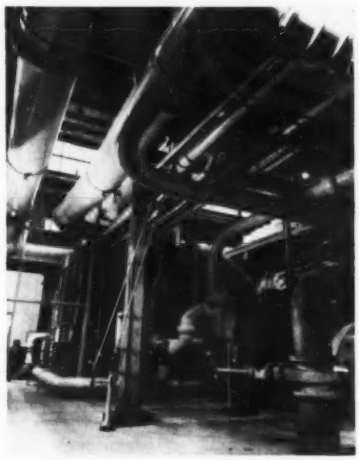
Key:—1 Half-pond; 2 Exit- or transfer-bay; 3 Burst bay; 4 Detention tank; 5 Effluent treatment; 6 Coffin decontamination; 7 Coffin storage; 8 Basket decontamination and drying area; 9 Transport coffin loading; 10 Transit coffin loading; 11 Office and workshop; 12 Change-room block, and 13 Switchgear.

positioned accurately on each of a fixed lattice of positions on the pond floor.

Special fuel elements, such as thermocouple elements, arrive at the pond singly in a general-purpose coffin conveyed by lorry to the "burst" bay end. This coffin is not immersed in water, but the element is dropped down a chute into a waiting skip. It is intended that burst fuel elements be treated similarly. The burst bays are separated from their half-ponds by a well with a gate through which the skip handling machine and skip may pass. The division tends to confine to the "burst" bay any extensive contamination which may arise from a bad burst.

Off to Windscale

Irradiated fuel elements are ultimately conveyed to Windscale in transport coffins on road transporters, the coffin containing the skip as well as the fuel elements.



Dump condenser with ancillary pipework in turbine hall basement
(Photo by courtesy of Stewarts and Lloyds)

Pond Water Treatment

Pond water from town supply is first softened and then dosed with caustic soda to pH 11-11.5 to minimize fuel element corrosion. About 3 per cent. of the contents of each half-pond is drawn off daily to keep the pH value up and activity down. The off-take is fed to a "dirty" detention tank, which also receives the washings from decon-contamination vats and pond "sweepings" from a special squeegee device. The contents of the detention tank are filtered, transferred to a "clean" detention tank and either discharged to the Solway or, in some circumstances, returned to the pond. The effluent is only discharged whilst cooling-water pond purging is being carried out, and decay pond effluent is monitored so as to control the discharge of activity to permissible limits.

The filters are periodically back-washed, centrifuged, and the solid matter despatched to Windscale for storage.

Basically the turbine house at Chapelcross is the two Calder turbine houses placed end to end with an additional bay, and contains eight turbo-alternator sets. There are, however, points of difference from Calder.

No steam receivers are used, thus providing more room in the basement. This extra space has been used to some extent to accommodate the C.W. pumps in the turbine house, and four 50,000 gal/min pumps are installed there. Concrete culverts throughout are used for the C.W. system. Instead of the 12 smaller main feed pumps at Calder, Chapelcross will have eight 650 klb/hr main feed pumps but the same standby d.c. pumps as at Calder.

A conspicuous external difference at Chapelcross is the absence of the familiar Calder steam pipe bridges between reactors and turbine house. The steam pipes at Chapelcross are run in open trenches.

The cooling towers are of the same capacity and design as at Calder, with minor foundation changes. Make-up water is taken from the river Annan at a normal maximum rate of 6m. gal/day. Purge water runs under gravity to the Solway and is used to dilute decay pond effluent.

The main electrical system of the plant is generally similar to that at Calder but lacks the complications introduced there by the feeders to Windscale. Ultimately Chapelcross is to be connected at 132 kV to Dumfries by one line, to Galashiels by one line and to Harker by two lines.

Building Programme

Work began on site in July, 1955.

The most remarkable feature of construction at Chapelcross is probably that all four reactors were being built simultaneously and are timed for completion at roughly four-monthly intervals. This has required a large site organization on the part of the consultants to ensure a high standard of work and co-ordination.

The main runway was used at one end for hard standing for pressure

Precipitator units in a burst slug detection room

Pile control room of No. 1 reactor at Chapelcross

vessel construction, and along its length parallel to the reactors for transport of pressure vessel sections. Rail tracks on either side of the reactor line were used for traversing derricks.

Three existing hangars were used; one for heat exchanger fabrication, half of another for storage and shot-blasting of heat exchanger tubes, and the remaining one and a half as stores. Other existing buildings were used as workshops, offices and hostels, with certain additions.

The existing airfield electrical supply system was reinstated and augmented by a 3,000 kVA, 11 kV ring main with four 11 kV/415v substations. Steam supplies were provided by three oil fired 10 klb/hr boilers, and water supply to the site had to be increased to meet the needs of construction.

Although most of the construction methods were based on Calder experience, certain modifications and improvements were possible, notably in the erection of thermal and biological shields. Pressure vessels were shot blasted internally after stress relief and pressure test, instead of being wire-brushed as at Calder.

Reactor 1 was handed over to Operations on October 31st, 1958, and was loaded to critical size by November 9th. The first electrical export to the network of the SSEB took place on February 26th, 1959.

Acknowledgement

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CHAPELCROSS CONTRACTORS

Among contractors and suppliers of equipment for the Chapelcross project are the following:—

Accles & Pollock, Ltd. (stainless steel tubing); A.E.I. Lamp and Lighting Co., Ltd. (light fittings—turbine hall control room); W. H. Allen, Sons & Co., Ltd. (main circulating water pumps); D. Anderson & Sons, Ltd. (roofing); Appleby & Ireland, Ltd. (control rod indicators); Armstrong Whitworth (Metal Ind.), Ltd. (pressure vessel shield plugs and wall seal assemblies); Babcock & Wilcox, Ltd. (heat exchangers, cartridge cooling pond equipment); Sir W. H. Bailey & Co., Ltd. (low pressure C.W. valves); Baird & Sons (electrical work); William Beardmore & Co., Ltd. (steel plate for thermal shield); F. W. Berk & Co., Ltd. (Schori Division) (shot blasting of pressure vessels); J. Blakeborough & Sons, Ltd. (gas valves and control gear); William Boby & Co., Ltd. (two make-up deaerators); John Boyd & Co. (Engineers), Ltd. (15-ton O.E.T. crane); British Acheson Electrodes, Ltd. (moderator graphite); Brookhirst Switchgear, Ltd. (motor starters and panels); Broom & Wade, Ltd. (diesel-driven air compressors); Burnden Park Engineering Co., Ltd. (charge pan components); Burnett & Lewis, Ltd. (gas drying plant); W. P. Butterfield, Ltd. (irradiation hood tubes and liners); Butters Bros. & Co., Ltd. (derricks); The Carbon Dioxide Co., Ltd. (carbon dioxide); Chatwood-Milner, Ltd. (reactor components); Colvilles, Ltd. (reinforcing bars); Colt Ventilation, Ltd. (ventilation); Concrete, Ltd. (precast floors and roofs); Consett Iron Co., Ltd. (mild steel plates); Contactor Switchgear, Ltd. (auxiliary contactor starters); William Cooke & Co., Ltd. (thermocouple and lifting cable); Cravens, Ltd. (shield plugs and spent fuel skips); Crossley Brothers, Ltd. (standby diesel generating sets); Curfew Doors and Shutters, Ltd. (fireproof doors); The Darlington Insulation Co., Ltd. (reactor thermal insulation); Darlington Fencing Co., Ltd. (site fencing); Delapena & Son, Ltd. (induction heating equipment); Dewrance & Co., Ltd. (mountings and valves); Dicks Asbestos & Insulating Co., Ltd. (gas plant insulation); The Distillers Company, Ltd. (gas storage and evaporation plant); Distington Engineering Co., Ltd. (shield cooling stacks and three transport coffins); The Electric Furnace Co., Ltd. (heat exchanger stress-relieving equipment); Elliott Bros. (London), Ltd. (BSD gear, recorders, transmitter gauges, etc.); James W. Ellis & Co., Ltd. (steelwork); E.M.B. Co., Ltd. (control gear for mechanical handling plant); English Electric Co., Ltd. (auxiliary switchgear and control equipment); English Steel Forge & Eng., Ltd. (steel plate for thermal shield); E.R.F., Ltd. (transport vehicles for coffins); Ericsson Telephones, Ltd. (P.A.B.X. telephone equipment); Evans Lifts, Ltd. (lifts in reactor buildings); Fairey Aviation Co., Ltd. (graphite restraint equipment); Film Cooling Towers (1925), Ltd. (water coolers for auxiliary circuits); Alexander Findlay & Co., Ltd. (structural steelwork); Hackbridge & Hewittic Electric Co., Ltd. (11.5 kV reactors); Hadfields, Ltd. (control and shut-off rods); Matthew Hall & Co., Ltd. (heating plant); Ham, Baker & Co., Ltd. (penstocks and sluice valves); Haywards, Ltd. (lantern lights and steel doors); Heather Filters, Ltd. (air filters); Henry Hargreaves & Sons, Ltd. (ducting); W. T. Henley's Telegraph Works Co., Ltd. (11 kV and l.v. cables and accessories); James Howden & Co., Ltd. (shield cooling fans); Imperial Chemical Industries, Ltd. (stainless steel pipework for BSD gear); R. Jenkins & Co., Ltd. (mild steel ductwork); George Kent, Ltd. (recorders and instruments); The Walter Kidde Co., Ltd. (fire alarms and automatic extinguishers); James Kilpatrick & Son, Ltd. (lighting, heating and plug point installation); Richard Klinger, Ltd. (cocks for burst cartridge detection gear); Limmer and Trinidad Lake Asphalt Co., Ltd. (road finishing); Magnesium Elektron, Ltd. (fuel can material); Mather & Platt, Ltd. (gas circulator motors, fire fighting installation); The Mitchell Construction Co., Ltd. (main civil contractors); Metropolitan-Vickers Electric Co., Ltd. (frequency converter and control rod actuators); Munro & Miller, Ltd. (two oil-storage tanks); Newalls Insulation Co., Ltd. (thermal insulation); Newburgh Engineering Co., Ltd. (charge pans and fuel element strut assemblies); Newman Hender, Ltd. (gas plant valves); New Western Engineering, Ltd. (instrument installation and commissioning); Northumberland Whinstone Co., Ltd. (supply and delivery of aggregates); Pantak, Ltd. (radiography equipment); C. A. Parsons & Co., Ltd. (gas circulators, ductwork, generating plant); The Permutit Co., Ltd. (water treatment plant); Plessey Nucleonics, Ltd. (burst cartridge detection gear); Pollard Bearings, Ltd. (graphite support bearings); Pyrotenax, Ltd. (thermocouplings); The Redheugh Iron & Steel Co. (two horizontal oil-storage tanks); Reid Bros. (painting and glazing); A. Reyrolle & Co., Ltd. (11.5 kV switchgear, l.v. distribution); Rubery Owen & Co., Ltd. (liner tubes); Sandall Precision Co., Ltd. (control rod details, fuel struts); James Scott & Co., Ltd. (electrical construction supplies); Siemens Bros., Ltd. (cable racking); Simms, Sons & Cooke, Ltd. (dormitories, bungalows, kitchens, etc.); Standard Telephones & Cables, Ltd. (operational telephones); The Stanton Ironworks (C.I. special pipes and Victaulic joints); Steels Engineering Products, Ltd. (20-ton lorry-mounted mobile crane); Stewarts and Lloyds, Ltd. (H.P. and L.P. piping and valves); R. B. Stirling & Co., Ltd. (ductwork); A. A. Stuart & Sons (Glasgow), Ltd. (admin. building and police lodge); Strachan & Henshaw, Ltd. (reactor fuelling machines); Sulzer Bros. (London), Ltd. (six boiler feed pumps); Tarslag, Ltd. (effluent drain to Solway); Taylor Woodrow Construction, Ltd. (preliminary works); Transformers (Watford), Ltd. (415/110v transformers); David Thompson & Sons, Ltd. (heating services, control building); John Thompson, Ltd. (CO_2 storage tanks); Vacu-Blast, Ltd. (shot blasting equipment for heat exchangers); Versil, Ltd. (heat insulation of pipework, etc.); Vokes Genspring, Ltd. (pipe supports); The Vulcan Foundry, Ltd. (flux scanning gear); Wakefield-Dick Industrial Oils, Ltd. (lubrication); Wallace & Tiernan, Ltd. (chlorinating plant); T. W. Ward, Ltd. (installation of graphite, machinery, etc.); G. & J. Weir, Ltd. (feed water regulators); James M. Wells & Co., Ltd. (workshops and stores buildings); The Wharton Crane & Hoist Co., Ltd. (O.E.T. cranes); E. H. Wheeler (Scotland), Ltd. (electrical installation of main admin. block, etc.); Whessoe, Ltd. (pressure vessels); Whipp & Bourne, Ltd. (rectifier switchboards); Widnes Foundry & Engineering Co., Ltd. (cast-iron coffins); Yorkshire Electric Transformer Co., Ltd. (11.0 kV and l.v. transformers).

RADIOACTIVE ISOTOPES *for* *Measuring Engine Wear*

by

S. J. Walker

and

R. F. Pywell

British Petroleum Co., Ltd.

Fig. 1.—Fitting piston with radioactive ring to engine of Morris Oxford car used in experiments described in this article

UNTIL a few years ago the methods employed for determining the wear of engine components entailed weighing or measuring the part under test before and after a test run of at least 100 hr duration. Due to differences within manufacturing in surface finish and initial dimensions, of components, it was often necessary to conduct a number of repeat tests before the effects of fuel, lubricating oil and engine variables on engine wear could be accurately assessed. It will be appreciated that such wear investigations were both extremely time consuming and costly; up to three weeks of continuous engine operation was required to obtain a single result. Thus many problems associated with engine wear, although worthy of investigation, were not examined because of the time and cost involved.

With the development of the use of radioactive isotopes, however, the position changed radically. In April, 1953, a team was set up at the Research Laboratories of the British Petroleum Co., to investigate their application as tools in the study of the performance of engine fuels and lubricants in general, and of the factors affecting engine wear in particular.

In an internal combustion engine, wear of the piston rings and cylinders is normally the criterion for deciding major engine overhaul schedules; this wear manifests itself in increase in oil consumption and loss of performance. It was natural, therefore, that attention should be given to the possibility of using radioactive isotopes for determining the wear on these components.

A diagrammatic arrangement of the method used for assessing the wear is given in Fig. 2. As the engine runs the radioactive wear debris from the irradiated component passes with the lubricating oil into the engine sump, and a separate pump circulates the oil past a radiation detector. This detector and its

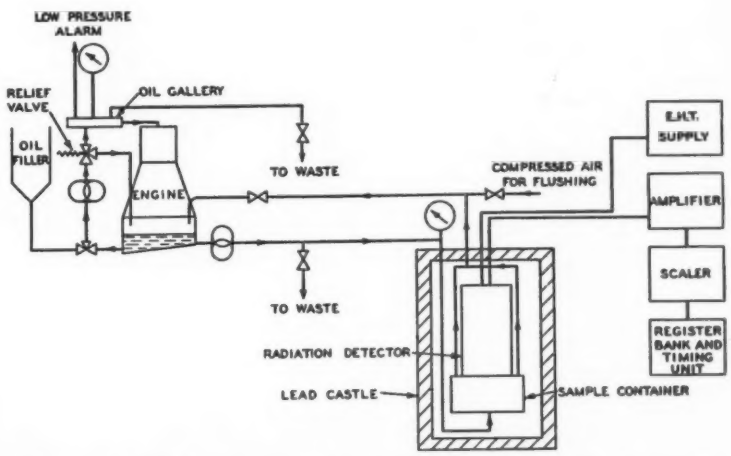


Fig. 2.—Diagrammatic arrangement of equipment used at BP laboratories for measuring engine wear with radioisotopes

associated apparatus counts the radiations from the wear material, and changes in the count rate indicate increases in the wear of the irradiated component.

This method of continuous monitoring requires the oil to be under pressure in the detecting chamber, and hence a metal container of sufficient thickness to withstand the pressure must be used. Because of this, it is only possible to measure the gamma radiation of the debris, since the shielding presented by the container will absorb the beta radiation.

It is convenient to carry out bench testing in single cylinder engines in order to minimize the volume of the lubricating oil charge, for ease of overhaul, and to decrease costs of operation at the BP Research Centre. A petrol engine specially designed for laboratory test work, and a diesel engine capable of being operated with direct or indirect fuel injection systems, are employed on this work.

One Ring Tested

Of the two engine components considered, the piston ring was initially selected as the one showing most promise for the successful application of the technique. Only one piston ring, the top one, is irradiated for ring wear investigations. The inclusion of other activated rings would only complicate engine assembly and wear assessment without adding appreciably to the data gained.

The main element in the material of the ring is iron, of which one isotope, Fe58, when irradiated in a neutron flux, gives Fe59. This isotope has useful gamma energy levels and half life, although the abundance and excitation cross-section are rather low. There are other elements making a significant contribution to the gamma radiation and these are shown in relation to the iron in Table I.

Table I.—Radioactive Characteristics of Piston Ring Material

Element	Radio-isotope produced	Specific activity after four weeks at 10^{12}n/cm²/sec mc/gm	Amount in a piston ring gm	Activity mc	Half life	Gamma energy MeV
Iron ..	Fe59	0.24	7.0	1.68	45.1 days	1.1, 1.3
Chromium	Cr51	66	0.038	2.51	27.8 „	0.323
Cobalt ..	Co60	85	0.0031	0.26	5.25 years	1.17, 1.33

BEPO Used

The piston rings are irradiated in the BEPO pile at Harwell for four weeks at a thermal neutron flux of about 10^{12} neutrons/cm²/sec. This gives a total activity for a 7 gm ring of 4.45 mc.

A decay curve for the ring material is given in Fig. 3. Seven days after removal from the pile 39 per cent. of the total activity is due to iron, 54 per cent. due to chromium and 7 per cent. to cobalt. After 100 days this has changed to 44 per cent. due to iron, 26 per cent. to chromium and 30 per cent. to cobalt.

From the figure of total activity it will be seen that transporting the ring presents little problem. The ring is placed inside a $5\frac{3}{4}$ in. diameter lead castle (Fig. 4.), giving $1\frac{1}{2}$ in. of shielding, which, in turn, is inside a wooden carrying box. The activity on the outside of the box is then within the Class 2 requirements for transport by rail, which states that it will be conveyed by direct through-routes, but must be stowed at least 4 ft from any other goods.

Although the total activity is small, when using an activated ring, certain precautions have to be taken in accordance with Home Office regulations, to protect the health of the operating personnel. In the BP laboratories the test engines for this work are installed in a cubicle separated from other work and, in addition, all radioactive materials are stored in a special store. Staff employed on the work have periodical medical examinations and blood counts, and carry a radio-sensitive film badge. During the fitting of the piston ring the staff wear overalls, gloves and face masks (Fig. 5).

Specially designed tools (Fig. 6) are used for fitting the ring to the piston and subsequently assembling it into the engine. They consist of long handled tongs for transferring the ring from the container to the piston, which is already assembled on the connecting rod in the engine. Bars are attached to the cylinder block and head for lifting and fitting these, in turn, on to the engine. The block and head then provide sufficient shielding to obviate the necessity for the further wearing of protective clothing, and the assembly of the engine and its associated gear can continue in the normal way.

The normal cast iron liner fitted to the engine considered to be most suitable for this work weighs 1.9 kg.

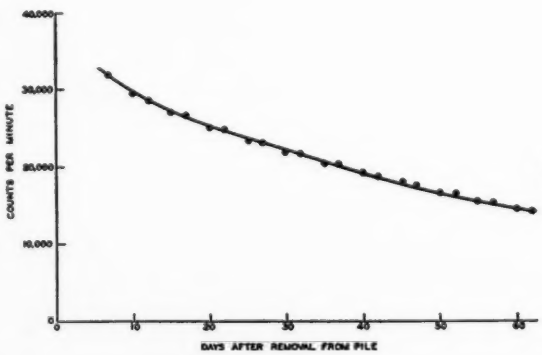


Fig. 3.—Radioactivity decay curves for ring fragments

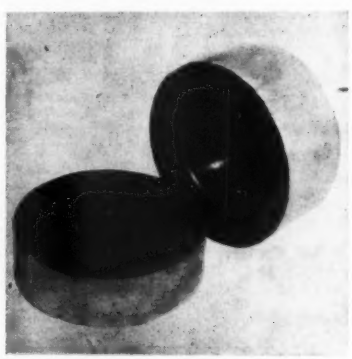


Fig. 4.—Lead castle for piston ring transportation

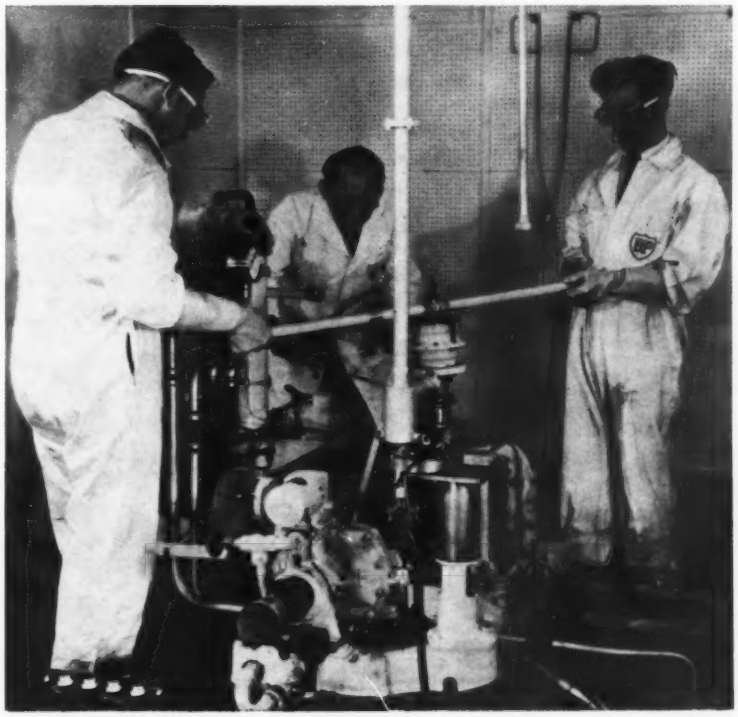


Fig. 5.—Fitting engine used in bench tests with a radioactive piston ring. This is carried out in a cubicle separated from all other work in the laboratories and the staff have periodic medical tests and blood counts

It is obvious that the initial activity of such a large mass, when activated at a level to give detectable wear over at least three months would be so high that a considerable handling problem would exist. Only a thin skin of the liner needs to be active cast iron, but bulk is required for strength and ease of assembly.

These considerations led to the investigation of the possibility of manufacturing a composite liner, the inner, or working, skin of which would be cast iron and the outer of some material that had either a low specific activity or short half life. It was also necessary to have a good bond between the two materials. In the automotive industry, a process known as "Al-Fin" has been developed for bonding aluminium and cast iron for the manufacture of brake drums and engine components. With the co-operation of Wellworthy Ltd., this proved to be a satisfactory method for producing the composite liner. Pure aluminium has a very short half life; however, a number of other elements, notably copper and manganese, are present in the alloys most suitable for bonding, and these markedly affect the total activity and rate of decay of the liner, as shown in Table II.

Comparisons Made

The analysis of the radioactivity of the cast iron is shown in Table III.

The total activities of both the alloy and cast iron parts of the liner, using either alloy A or alloy B, are shown in Table IV and the values are compared with the component that

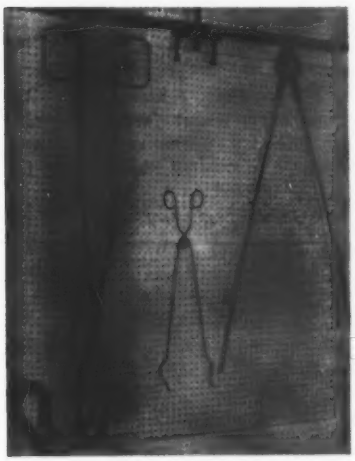


Fig. 6.—Specially designed tools for fitting radioactive rings to piston

Table II.—Radioactive Characteristics of Aluminium Alloys

Element	Weight of element in liner, gm		Activity of alloy after irradiation with 7.5×10^{11} n/cm²/sec for one week, mc					
			Alloy A			Alloy B		
	Alloy A	Alloy B	0 Days	7 Days	100 Days	0 Days	7 Days	100 Days
Copper	31.2	8.65	22,000	1.0	0.00	6,080	0.53	0.00
Nickel	16.0	11.8	100	1.48	0.75	75	1.10	0.55
Magnesium	11.8	10.4	20	0.00	0.00	17	0.00	0.00
Iron	4.15	4.85	1	0.63	0.45	1	0.74	0.53
Silicon	4.15	90.0	6	0.00	0.00	132	0.00	0.00
Titanium	1.4	1.4	27	0.05	0.02	27	0.05	0.02
Lead	0.35	—	0	0.00	0.00	—	—	—
Tin	0.7	—	7	0.08	0.02	—	—	—
Zinc	0.7	—	27	0.53	0.40	—	—	—
Aluminium	619.1	562.0	59,500	0.00	0.00	54,000	0.00	0.00
Manganese	—	1.4	—	—	—	4,080	0.00	0.00
Total	690	690	81,700	3.77	1.64	64,400	2.42	1.10
Total γ activity			81,700	3.05	1.00	64,400	1.73	0.47

Table III.—Radioactive Characteristics of Cast Iron Liner

Element	Weight of element in liner, gm	Activity of cast iron after irradiation with 7.5×10^{11}n/cm²/sec for one week, mc					
		β and γ radiation			γ radiation only		
		0 Days	7 Days	100 Days	0 Days	7 Days	100 Days
Carbon	2.45	0	0	0	—	—	—
Silicon	1.42	2.08	0	0	0.0014	0	0
Sulphur	0.057	0.076	0.053	0.006	0.004	0	0
Phosphorus	0.40	7.5	5.3	0.059	—	—	—
Manganese	0.57	1660	0	0	1660	0	0
Chromium	0.285	4.5	3.8	0.35	4.5	3.8	0.35
Cobalt	0.0176	0.536	0.29	0.28	0.536	0.29	0.28
Iron	51.8	8.17	7.84	5.7	2.75	2.42	0.605
Total	57	1680	17.27	6.34	1670	6.51	1.19

formerly had the highest activity used in this laboratory, which was the diesel engine piston ring.

It is noted that the activity of the liner after seven days is little more than that of the Petter engine piston ring.

Although the aluminium reaches a high activity, its half life of 2.3 minutes makes it far less trouble than the manganese and copper (2.58hr and 12.9hr) and the relatively longer high activity of these components necessitates storage of the liner for a week before it is brought into use. The co-efficient of thermal expansion of alloy A is so different from that of cast iron that the material is unsuitable, and therefore alloy B is used in this work. Fortunately, this alloy also has the lower initial activity.

Wear is Tested

Before using a composite liner in an engine instead of a normal solid cast iron liner to study wear problems, it was necessary to ensure that anomalous results would not be obtained. Tests were made, therefore, to ensure successful mechanical operation of the composite liner and to determine the liner skin temperatures and wear rates on both the composite and solid cast iron liner. These points were investigated in turn. The liner was run in an engine for 200hr and found to be satisfactory; a temperature survey was carried out to enable comparable skin temperatures to be reproduced under a wide range of operating conditions; and normal wear tests, in which similar wear rates were obtained, were conducted.

The transportation and installation of the liner presented a number

Table IV.—Activity of Engine Components

Source	Total γ activity of source, mc		
	0 Days	7 Days	100 Days
Liner, using Alloy A	83,400	9.56	2.19
,, ,, ,, B	66,100	8.24	1.66
Petter engine piston ring irradiated at 10^{12}n/cm²/sec for four weeks	9.22	7.91	1.23

of engineering problems, and some ingenuity was required to overcome them. It was necessary to carry out what is normally a fairly complicated assembly process without any direct handling or visual examination of the liner. The casket, used both for transporting the liner and subsequent assembly, was made of mild steel and weighed approximately 3 cwt.

A tool (Fig. 7), was manufactured for fixing the two lower water sealing rings on to the liner and a press and jacking system for pressing the liner into and out of the cylinder block.

Fig. 7.—Sealing ring being fitted to the liner

Other tools included an illuminated mirror, tongs and cutting instrument.

With a team of personnel who had trained together beforehand, the operation of installing the liner from initially opening the casket to fitting the cylinder head takes approximately 20 min, which is little more than that taken for a non-irradiated liner. The equipment has been so designed that, should a fault occur in the assembly process, the liner can be returned to a safe position. Throughout these operations the same personal safety precautions are taken as when fitting the irradiated ring. A check of the radiation dosage has been made and the average to which personnel are subjected is 1 millirad for 20 min.

Soon after data had been obtained on piston ring wear in one of the bench engines it was thought advisable to examine the validity of some of the conclusions in a multi-cylinder engine. As early as 1955 these laboratories were operating a Morris Oxford car with a radioactive piston ring fitted to No. 1 piston.

Same Doses Given

The period and intensity of irradiation of the ring was similar to that for the bench engine work. It was necessary to remove the engine from the chassis to fit the ring and to

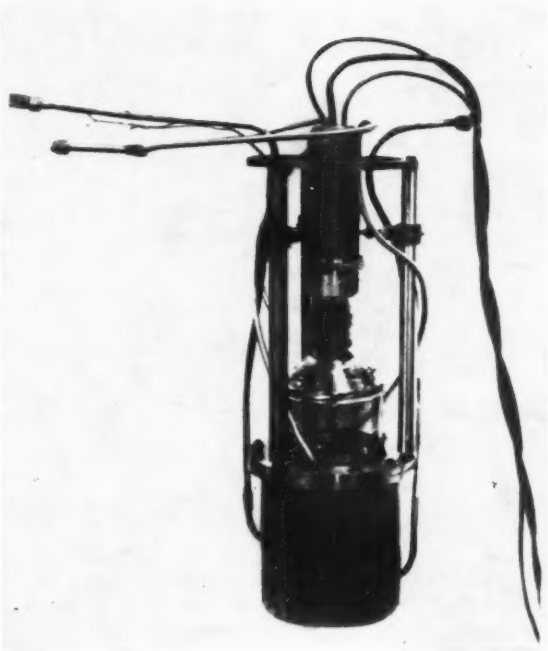


Fig. 8.—Scintillation counter assembly as fitted to one of the engines. It is found to be more sensitive than Geiger tubes

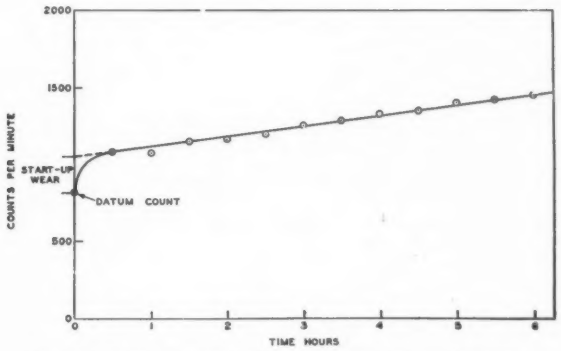


Fig. 9.—Typical test graph of counts/min against running time

complete the assembly of the engine. This operation is illustrated in Fig. 1. During this operation the maximum radiation to which the fitters were subjected was 0.1 millirad/hr. With the engine assembled into the vehicle the radiation level at the outside of the bonnet and at the driver's feet was 2.5 and 0.9 millirad/hr respectively.

The radioactive waste materials consist of:—

Liquids—oil and cleaning fluid used in the engine; and

Solids—rings, liners and engine deposits in which radioactive debris has accumulated.

Once Only

The liquids are drained from the engine and detecting chamber into a barrel below the engine level. After approximately one week the contents of the filled barrel are transferred to cans, monitored to ensure that the level of radioactivity is harmless and burnt in steam raising plants. Radioactive rings are only used once and are then deposited in a large bore pipe sunk 6 ft into the ground. Liners are used twice and when not in use are stored in a marked compound. They are eventually disposed of in a similar manner to the rings. Any other solid material such as pistons and gaskets are carefully monitored before being disposed of in the normal way.

The detecting equipment used initially consisted of six lead cathode organic quenched Geiger tubes. The sample chamber was made from a solid drawn stainless steel tube shaped to minimize sedimentation. A small air gap was made between the tubes and chamber and an air supply arranged to pass over the tubes, thus obviating the necessity for cooling the oil. The tubes and sample chamber were located inside a $1\frac{1}{2}$ in. thick lead shield. This equipment was used in conjunction with a probe unit, a scaling unit and a timing and counting unit and an EHT power supply. The timing and counting unit was designed to count the output of the scaling unit on one of a series of mechanical registers. Each register counts for half an hour, and at the end of this time a relay switches the scaler output to the next register.

To Improve Counting

One disadvantage of Geiger tubes, even when used as a nest, is that the efficiency of counting is low, and it is not possible to detect small changes in wear. However, the use of more sensitive detectors such as phosphors overcomes this to a great extent. Scintillation equipment has now been fitted to one of the engines using a $4\frac{1}{2}$ in. diameter and 2 in. thick thallium activated sodium iodide crystal (Fig. 8). The output from the scaling unit is registered on a timing and counting unit designed for mechanically registering up to 25 pulses/sec.

The use of a scintillation counter necessitated the design of a new sample container. The oil from the engine is fed into the bottom of the vessel, which is made of stainless steel, passes round the crystal and leaves two diametrically opposed helical tubes at the top. Cooling air for the photocathode passes through the inside of the oil feed pipe and around the surface of the crystal. Additional cooling air passes between the sample chamber and the lead shield. This lead shield is surrounded in turn by a light tight can.

It has been found by a number of experiments that the scintillation equipment installed is approximately 25 times more sensitive than the nest of Geiger tubes.

The Method

A system has been developed which has the following characteristics:—

1. The ability to differentiate between the wear occurring during the early revolutions of the engine and that occurring under steady running conditions.

2. A direct comparison of the wear obtained under different operating conditions.

3. A comparison of wear data obtained on different rings or liners.

Before each run a background, or datum count is taken with the oil circulating through the detecting system (Fig. 9). The engine is started and immediately brought to the operating conditions. Fifteen minutes

after starting the counting equipment is switched in and the counts are registered over half-hour periods for the duration of the run, usually six hours. As the component wears the activity in the oil increases and so the half-hourly readings will also increase. At the termination of the test the average counts per minute for each half-hour of running are determined and from this data the best straight line is calculated. Thus the average increase in counts per minute for each hour can be assessed and this gives a measure of the steady running wear. The intercept of the calculated straight line on the ordinate is commonly appreciably above the datum point, indicating that there is a markedly higher wear rate immediately after starting. The difference between this intercept and the datum is termed the " start-up " wear. It is necessary to carry out duplicate runs at each set of operating conditions. The mean of these two is taken as the test result.

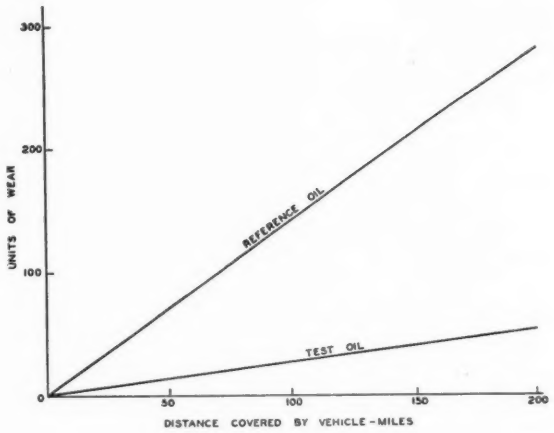


Fig. 10.—Relative wear in 200 mile vehicle test

Decay Allowance

The two figures obtained, one for start-up wear and the other for steady running wear, are modified to allow for the natural decay in the activity of the component. It is the practice to relate all determinations to the activity seven days after the end of irradiation. To determine this correction factor a fragment of ring material is irradiated with the test ring and clamped to a single GM tube so that the geometry is not changed throughout the life of the fragment. The activity is then checked approximately every three days.

A typical decay curve is shown in Fig. 3. Approximately every sixth test a standardizing check is carried out. The engine is operated at a standard speed, power output and jacket temperature on a reference fuel and lubricating oil. The results obtained on the test programme are then related to the steady wear occurring under these standardized conditions. This method has been adopted because it has been found that wear rates vary under apparently identical conditions, not only between different rings and liners but also over periods within a given component's life. Because of this any direct conversion of rate of increase of activity to wear in terms of weight loss would not enable true comparisons of the effect of operating variables to be made.

In the vehicle tests the car was started from cold for each run to give the most adverse operating conditions. Each run was five miles in length, which was representative of the length of journey commonly experienced in this country, and each test was for 200 miles. The activity in the oil was measured and the result plotted for each day's operation. At frequent intervals a test was made with a reference oil. Thus the result on the test oil could be expressed as the ratio of the increase in activity of the test oil to the increase in activity of the reference oil. Some of the results obtained from this work are illustrated (Fig. 10).

Results Coincide

This work confirmed the previous bench engine test findings and with subsequent work suggests that bench tests give a reliable indication of road performance.

It is apparent that similar techniques to those described above may be used for measuring the wear of other engine components. However, there are a number of limiting factors.

(1) The material of the component should radiate at a high enough level for differences in wear rate to be assessed.

(2) The component should retain its activity long enough for sufficient comparative tests to be conducted to justify the complication and cost of this method over conventional methods.

(3) It should be possible for the irradiated component to be installed in the engine without subjecting personnel to hazardous radiation.

One of the major advantages of the use of radioactive isotopes over conventional methods for measuring engine wear is the saving in time. This manifests itself in the shorter test duration and obviates the overhauling of the engine between tests. This second point had the advantage of enabling a direct comparison to be made between various factors influencing wear without disturbing the cylinder assembly.

A Saving Achieved

A further advantage is that the bench test technique enables the factors which affect " start-up " wear to be studied. This is important since " start-up " wear in some types of operation can represent a large part of total wear, and other methods are unsuitable for such work. Far more expensive measuring equipment is required than for conventional tests, but nevertheless this is not a major consideration.

It has been estimated that a considerable saving in cost with this comparatively new method over conventional methods has been achieved and it is reasonable to expect that, with further experience and development, this saving will be increased.

The authors wish to thank the chairman and directors of the British Petroleum Co. for permission to publish this article and Wellworthy, Ltd., AERE, Harwell, and their colleagues at the BP Research Centre for their co-operation.

NUCLEAR ENERGY DEVELOPMENTS IN

CANADA

Canada is in no urgent need for economic nuclear power—there are an abundance of conventional fuel and large sources of untapped hydro-power in the country. Consequently she can take her time in developing an efficient economic nuclear power station. It is hoped that the first full-scale station will be in operation by 1968. A pilot plant for this is now under construction—the 20 MW NPD-2—due to be ready for operation in 1961.

by J. BURKETT

GENERALLY speaking, Canada has an abundance of conventional fuel and water power. The latter has been the major source of electricity but in certain areas economic hydro potential is becoming exhausted. There are still large resources of undeveloped hydro power in British Columbia, Manitoba, Quebec and Newfoundland. Very great reserves of oil, gas and low cost coal are located in Alberta and Saskatchewan. In Eastern Canada, however, where there is a large concentration of industry, hydro resources have been almost fully developed. In Southern Ontario, for instance, where there is a great demand for power, it is estimated that hydro resources will be used up by the early 1960s. Coal for thermal power stations has to be imported from the United States, resulting in high power costs. It is only with hydro power that Eastern Canada has been able to enjoy competitive cost advantage over other parts of the nation.

Apart from this area there seems to be no foreseeable demand therefore for nuclear power. In some regions fossil fuels may remain economical long after nuclear power is competitive elsewhere. Certain remote areas might use nuclear power plant of fairly low capacity even at high cost because of the high transportation cost of conventional fuels.

Canada's objective is for nuclear power at under 6 mills/kWh (excluding the cost of research and development) and it is hoped that the first large plant will be in operation no later than 1968. This time interval will permit the continuance of development work and sufficient time to solve major problems in the construction and operation of the selected reactor. The following programme for installed nuclear capacity has been suggested as a possible target:

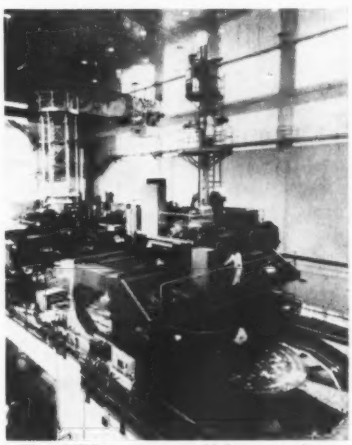
by 1966 ..	.. 200—1,000 MW
1971 ..	.. 600—1,700 MW
1976 ..	.. 2,000—3,300 MW
1981 ..	.. 4,000—7,000 MW

A-Bomb the Start

The first stage of Canada's atomic energy programme began in January, 1943, when she joined with the United Kingdom and the United States in the development of the atomic bomb. Canada supplied the uranium and undertook research to find a method of producing plutonium. The joint Canadian-United Kingdom project was administered by the National Research Council of Canada, and operated at Chalk River, about 130 miles from the city of Ottawa. The first facility to be provided was the Zero Energy Experimental Pile which went into operation in September, 1945, for the purpose of studying the value of a heavy water natural uranium system in the event that the graphite uranium system proved unsuccessful. The NRX (National Research X-perimental) reactor followed, equipped with six loops for studying fuels, cladding and structural materials. During its years of operation it has played an important function as a powerful research tool providing both the United States and the United Kingdom with facilities for nuclear studies.

A larger reactor, NRU, with higher power and higher flux followed in 1957.

In 1947, with the renewed partnership with the United States in the production of uranium, Canada sought the participation



The NRU reactor which went into operation at Chalk River, November, 1957

TABLE OF REACTORS

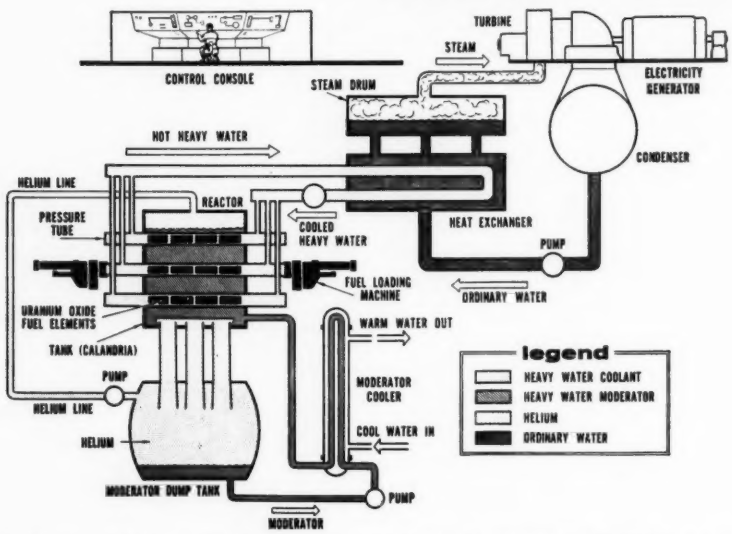
	Fuel	*Maximum Thermal Output*	*Net Electrical Output*	*Moderator*	*Coolant*	*Coolant Exit Temperature*	*Maximum Neutron Flux*	*Start-up*
Chalk River								
ZEEP .. .. (Zero Energy Experimental Pile)	Nat. U	10 W	—	D_2O	None	—	10^8	1945
NRX .. .. (Broke down December, 1952, restarted February, 1954)	Nat. U	40 MW	—	D_2O	H_2O	66-82 C.	6.8×10^{13}	1947
NRU	Nat. U	200 MW	—	D_2O	D_2O	75 C.	3×10^{14}	1957
PTR .. .. (Canadian Pool Test Reactor)	90 per cent. U^{235} 0.7 per cent. enr.	10 kW	—	H_2O	H_2O	—	2×10^{11}	1957
Power Reactor Experiment								
NPD-II	Nat. UO_2	82.5 MW	17 MW	D_2O	D_2O	277°C.	1.1×10^{14}	mid-1961

of the mining industry in the search for new deposits. Uranium was first mined in 1942 at the Eldorado mine on Great Bear Lake. By the end of 1957 uranium production was over 12 times as great as it was in 1945. The total 1957 production was valued at nearly $131m., much of it being exported to U.S.A. The estimated reserves are stated to be 334,100,000 tons containing 345,000 tons of uranium oxide.

D_2O Reactor Backed

In 1952, the Chalk River project was taken over by Atomic Energy of Canada, Ltd., a government-owned Crown company with a board of nine directors representing industry, public and private power companies and the universities. With the experience gained in the construction, operation and maintenance of the heavy water natural uranium type of reactor, the Canadians have developed the conviction that the heavy water reactor holds the best promise as the most economical means of deriving power from natural uranium, particularly in view of the large deposits available in the country.

(*Right*) **Artist's impression of NPD-2, due to be in operation by 1961. Electrical output will be 20 MW.** (*Below*) **NPD-2 flow diagram**



In 1955 AECL invited leading Canadian industrial companies to submit proposals for the design and construction of a nuclear power station to be known as NPD (Nuclear Power Demonstration). Canadian GEC was selected to serve as the prime contractor with Ontario Hydro providing the site, finance and design of the remainder of the plant, and operation. GEC was to contribute $2m. towards the engineering cost of the project whilst AECL agreed to find the balance in excess of GEC's contribution. Development work with NPD is mainly directed towards evolving a fuel element to withstand high burn-up, the fabrication of pressure tubes either in zircaloy, aluminium alloys or insulated aluminium alloys; and a mechanical method of fuel changing under power to minimize loss of heavy water.

In the original design of NPD-1, a steel pressure vessel system was selected because of its lower cost for a small reactor. During 1956 and 1957, a preliminary design of a 200 MW nuclear power station was worked out embodying the use of a pressure-tube type of reactor using zirconium alloys. In late 1957, it was decided to apply this new concept to NPD and designate the new design as NPD-2.

The fuel will be prepared in short sections, charged and discharged by remote control from both ends of the reactor, thereby leading to uniform irradiation and heat generation.

The 20 MW NPD-2 will serve as a pilot plant in a development programme for a 200 MW(e) station CANDU (Canadian Deuterium Uranium). According to the Canadians, it is believed that a 200 MW heavy water reactor can be built to compete with a coal-fired station having a fuel cost of $9/ton. This power rating is regarded as the maximum for the design in question, but it is suggested that an increase to 1,000 MW might be possible with greater operating experience.

Further details can be obtained from the following papers presented at the 2nd International Conference on the Peaceful Uses of Atomic Energy:—P/183—Canada's steps towards nuclear power; P/206—Long-run trends in conventional and nuclear power costs and their implications for Canada; P/207—Economic environment for nuclear power in Canada; P/208—Study of a full-scale uranium and heavy water nuclear power plant; P/209—The Canadian NPD-2 nuclear power station; P/211—The NRU reactor, and P/213—The control of Canadian nuclear reactors. Other useful references are "Atomic Energy in Canada—1956" and "Statement on Canada's atomic energy programme" published by Atomic Energy of Canada, Ltd. "Canada's first nuclear power station being built for Atomic Energy of Canada, Ltd., and Ontario Hydro" and "NPD—Canada's first nuclear power station" published by Canadian GEC, Ltd.

Aluminium Booklet

ADVANTAGES of aluminium usage in heat-exchanger fabrication are fully described in a new publication now available from Reynolds Metals Co., of Richmond, Virginia. Entitled "Reynolds Aluminium for Heat Exchangers," it summarizes in 16 pages of charts and pictures, technical information needed by the heating engineer, fabricator and industrial purchaser. The text covers aluminium heat transfer rates, temperature properties, tensile strengths, pressures and dimensional tolerances. Charts provide fingertip information on aluminium stress values, working pressures, thermal expansion and conductivity and friction factors.

'NUCLEARIST' writes . . .

"PUSILLANIMOUS" is an adjective which might well be applied to the British approach to nuclear energy education. When the nucleus was made to go through its paces only in the universities, and the atom was the prized possession of the back-room boys, it was justifiable perhaps that nuclear structures, characteristics and reactions should not have appeared in the curricula of schools and colleges. Eniwetok, Zeta, Bradwell, Harwell, tracers, cobalt-60—all have now come to mean something to people today, and yet our young people are not expected to know anything about these features which have such an impact on their lives! Authorities responsible for syllabus content grudgingly admit that students of university level should know a little of the electrons, protons and neutrons, but such items as nuclear fission and fusion must not rear their ugly heads until the post-HNC and post-degree years.

Can it be that to raise an ostrich head above the sands and to see that nuclear energy really is with us would involve a risk of having to spend more money on the equipment which teachers might require for illustrating nuclear science? Perhaps that is it. So only a few colleges of advanced technology are allowed to dabble in this modern alchemy. Yet in the U.S.A. the AEC has ambitious plans which for years have assisted a realistic approach to atomic energy in colleges—assistance with the planning of experiments, and with the acquiring of equipment and information. Even in Western Germany, where a much later start was made in the nuclear field, there was recently a meeting in Munich of 45 physicists from 19 engineering institutions in all parts of Germany, to discuss the introduction of nuclear physics into the curriculum of grammar schools. There is no intention of training specialists in this way, but merely of giving every engineer a groundwork in a subject without which he cannot be said to be fully trained by modern standards.

* * *

Government-baiting by backbenchers is no monopoly of the British parliamentary system. The Socialist Party of Germany (SPD) recently badgered for answers to its questions in the Bundestag. Would the Government give figures for the increase in the radioactivity level in air, waters, soil and foodstuffs over the last ten years, and its relation to the normal background? What effects would there be in Germany if nuclear weapons were tested in the Sahara? Whether the SPD expected answers or not, I do not know, but I am confident that they did not expect any answers free from political bias.

* * *

The costs of the Berlin reactor (BER) seem to be worrying the authorities. A breakdown of the figures reveals that the annual costs, in Deutsche Marks, are: depreciation at 10 per cent. 200,000; interest at 3.6 per cent. over 10 years, 40,000; interest at 4 per cent. on U-235, 5,000; or a total of 245,000DM as capital items. To this must be added the running costs, which are as follows; these figures being based on a 27 per cent. usage, or 2,400 hr/annum: use of U-235 (5g/year), with processing and transport, 2,000; cooling water, 8,000; electricity consumption, 20,000, and repairs and replacements, 25,000. The total costs are thus about 300,000DM/year, or about £500/week. This high figure must be justified by a much fuller utilization of the reactor, it is said. It makes one wonder to what extent a reactor is a matter of prestige. Surely these costs must have been accurately forecast. Or can it be that now the new toy is installed, the novelty has worn off, and the many people who thought they might like to use it have now changed their minds?

* * *

There is much less cause for dissatisfaction in Britain's latest industry, that of isotope production. Extensive new buildings are planned, ample evidence of the thriving state of this section of our nuclear industry. Last year we turned out £650,000 worth of radioactive isotopes. How does this compare with production in the U.S.A? Oak Ridge National Laboratory, the equivalent of our Harwell and Amersham establishments, produced last year 228,717 curies of isotopes, ranging from $50 to $5/curie. If we take the average price as $30/curie, this production is worth nearly $7m. or perhaps £2½m. Obviously, Britain's production is far behind the American one, but, on the other hand it is expanding very rapidly. Our soaring sales may soon mean equality with the Americans in this industry.

Also soaring is another type of nuclear production—that in the field of information and technical papers. Surely it is true to say that the benefits of unrestricted advance in nuclear science are not unmixed. The more hopeful the outlook for an Utopia, the more hopeless becomes the task of keeping abreast with developments. Research associations, industrial undertakings, education institutions—all are tearing out hair at the sheer impossibility of keeping track of the published work these days.

In the U.S.A., a new publication, *Nuclear Science Abstracts*, is intended to be the main reference for literature searching for atomic documentation. The editor, A. P. Bradley, the supervisor of the libraries of the Atomics International, certainly has an unenviable task. His library has been receiving each week about 1,500 cards, all of which have to be sorted and filed. Far too rapid has been the growth of these files, as is the case with other AEC contractors' files. New and improved techniques of reproduction and indexing may ease the problem, and in the *Abstracts* will now appear details of all new books and information, listed under subjects and author. Each 3, 6, 12 and 60 months, cumulative indexes will be published. But what a Herculean labour this will be!

In the U.K., too, there is the same problem, and the UKAEA is hoping to make more readily available atomic information. To this end, greater use will be made of microphotographs, a complete set of which can be bought for £120, covering the period 1947 to 1957. Sets of these have been presented to the International Atomic Energy Agency, European Nuclear Energy Agency, and Euratom. These two bold attempts to solve what is rapidly looking like an insoluble problem are very highly commendable, but wits will have to be kept keen if these attempts are not to prove abortive.

PEOPLE... in the NUCLEAR NEWS

The first Visiting Professorship to be arranged by the International Atomic Agency under its scheme of exchange of specialists has been held by **DR. A. G. MADDOX,** the Cambridge radiochemist. He has been giving a series of lectures at a radioisotope training course organized by the Greek Atomic Energy Commission. While in Athens, Dr. Maddox advised the commission on the operation of a provisional radiochemistry laboratory.

A **BRITISH-BORN** scientist who became a naturalized American in 1940 has returned to England to serve as science officer at the American Embassy in London. He is **DR. THOMAS H. OSGOOD,** a physicist, who since 1950 has been Dean of the

Dr. T. Osgood

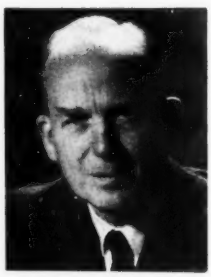
School of Advanced Graduate Studies at Michigan State University. Dr. Osgood's appointment is under the U.S. State Department's scientific officer programme, which has been re-established after a break of several years. Scientific officers have been appointed to the U.S. Embassies in Paris, Rome, Bonn, Stockholm and Tokyo, as well as to London. Similar appointments are to be made for the Soviet Union, India and South America. Dr. Osgood, who is 58 is married, with two children. He was born at Louth in Lincolnshire and received his PhD degree from Cambridge University in 1927. A physicist with both research and administrative experience, Dr. Osgood has done a good deal of work in the fields of scientific education and scientific publishing. He has been chairman of the Council of Sponsoring Institutions of the Associated Midwest Universities Programme of the Argonne National Laboratory, editor of the *American Journal of Physics*, and chairman of the publications board of the American Institute of Physics. He has also taken an active part in the International Union of Pure and Applied Physics. Before he went to the United States, Dr. Osgood was a Berry scholar and an assistant lecturer in physics at St. Andrews University, a Carnegie scholar at Cambridge, and an assistant lecturer at Manchester University. He held several teaching posts in America before going to Michigan in 1941.

Metropolitan-Vickers Electrical Co., Ltd., have appointed **MR. A. CORMACK,** BSc(Eng), GradIMechE, superintendent, special duties, of their Larne Works. He was formerly assistant superintendent of the company's Germiston works. His place there has been taken by **MR. R. HARRISON,** formerly general foreman.

MR. J. H. J. SUTCLIFFE ROSS, AssocIEE, has been appointed sales manager of the Metropolitan Electric Cable & Construction Co., Ltd. He succeeds **MR. T. C. JOHNSTON,** now a director and general manager of the company.

DR. W. I. PUMPHREY, DSc, manager of the research department of Murex Welding Processes Ltd., has been elected to the Court of Governors of the University of Birmingham.

The recent announcement of changes in the organization of the United Kingdom Atomic Energy Authority (see page 274) brings into the news the name of **SIR WILLIAM COOK,** CB, who in the short space of five years has proved himself to be one of the truly important leading men of the Authority. Sir William becomes executive head of the newly created Development and Engineering Group, among the responsibilities of which will be the design, development and construction of reactors and associated plant. This is an important responsibility and although certain development work in this field will continue to be



Sir W. Cook

undertaken by the Research Group, the direction taken by the Authority in the work on new reactor systems will depend largely on the new group, and its head. One of Sir William's first jobs will be the Authority's nuclear marine propulsion project. As a former chief of the Royal Naval Scientific Service this should be of particular interest to him. Sir William, who recently celebrated his 54th birthday, has spent most of his working life in civil service appointments and showed himself as a leader at a comparatively early age. A Bristol University graduate, he held various scientific posts from 1928 to 1947 with research establishments of the War Office and Ministry of Supply. In 1947 he was appointed director of Physical Research with the Admiralty. Three years later he became chief of the Royal Naval Scientific Service. He joined the Atomic Energy Authority in 1954 as deputy director of AWRE and gave this post up in 1958 to replace **SIR CHRISTOPHER HINTON** as Member of the Authority for Engineering and Production.

The new deputy director of the Atomic Research Establishment, Harwell, **DR. F. A. VICK,** OBE, has spent most of his life

Dr. F. A. Vick

in academic circles. At present professor of physics at the University College of North Staffordshire, he has held lecturing appointments at both the London and Manchester universities, was from 1950 to 1954 vice-principal of the university college of North Staffordshire and earlier this year was appointed to the University Grants Committee. Born in 1911 and educated at Birmingham University, Dr. Vick's first lectureship was with London University, where he was appointed assistant lecturer in physics at University College in 1936. Later he became lecturer. From 1939 to 1944 he left university life to become assistant director of research with the Ministry of Supply. From 1945 to 1950 he was lecturer and then senior lecturer in physics at Manchester University. He was appointed head of the physics department at University College of North Staffordshire in 1950. Dr. Vick takes up his new appointment later this year. As deputy director of Harwell he succeeds **MR. D. W. FRY,** who has been appointed director of the Atomic Energy Establishment, Winfrith.

Formerly general manager of production with Monsanto Chemicals Ltd., **MR. J. S. BROUGH,** MIChemE, MIMechE, has been appointed director and general manager of Humphreys and Glasgow Ltd. In this capacity he will act as deputy to **MR. G. G. FARTHING,** deputy chairman and managing director of the company. An associate of Manchester College of Technology, Mr. Brough was plant manager with Magnesium Elektron Ltd., during the war years and joined Monsantos in 1945 as chief chemical engineer at Ruabon.

ISOTOPES

ASSIST SEWAGE ENGINEERS

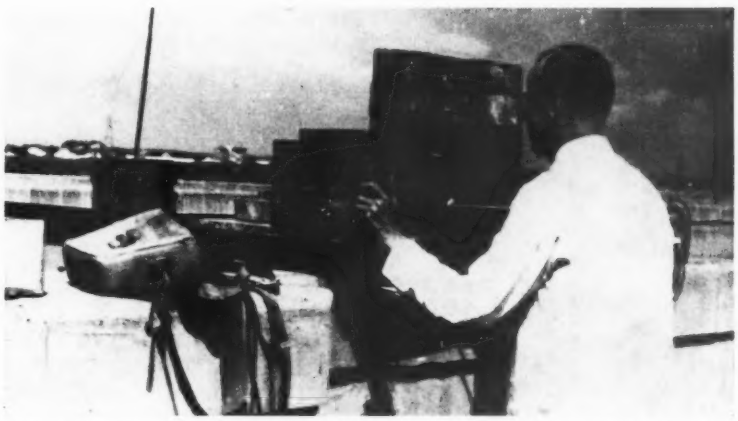
PART II

Recent Work Undertaken At London Sewage Works

(*Continued from page 198*)

DURING the early experiments all operators wore personal dosimeters and the radiation dose received did not exceed 0.2 rads in any one week. The radiation dose received by the body from the bucket during the 5-6 seconds of its tipping was, of course, very high—in the region of 300-400 rads/hr—and it was decided that for subsequent experiments some sort of protective shielding in the form of lead bricks had to be provided.

For the subsequent experiments a new type of counter head was constructed. A G26Pb tube was used, to give greater counting efficiency, together with an auto-transformer impedance-reducing circuit. These heads proved very satisfactory in use and will operate efficiently at distances of up to a quarter of a mile from the ratemeter. In order to operate six counter heads at a time, a special six-way switch box was constructed, embodying a six-way switch and a step-up circuitry to match the input impedance to the ratemeter.



Mr. Arthur Green, principal scientific officer in the L.C.C. public health department, prepared isotope for introduction into sewage behind protective lead wall

Owing to a cable defect it was possible to use only five counter heads in the next set of experiments. In these they were positioned equidistantly along the inlet weir, 1 ft downstream of the weir and submerged to a depth of 9 in. The results obtained are shown in Fig. 5.

At the outlet weir the counters were positioned on either side of the trough, at the exact centre of each of the three lengths of trough, 4 in. out from the weir and submerged to about 6 in. The results obtained are shown in Fig. 6. It will be seen that the passage of isotope over the weir was reasonably uniform except in the case of position 5.

Intermittent Scraping

At the time of the experiments with the isotopes, consideration was being given to altering the method of operation of the scrapers. It was

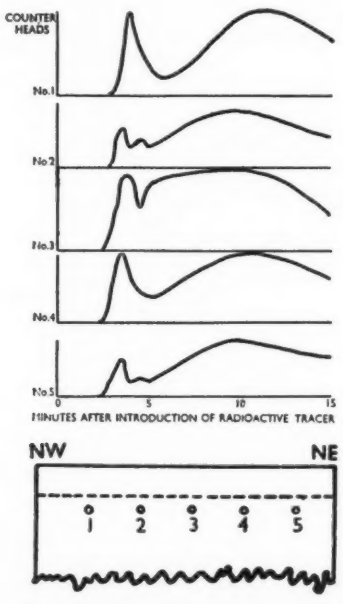


Fig. 5.—Distribution of sludge over inlet weir of primary sedimentation tank

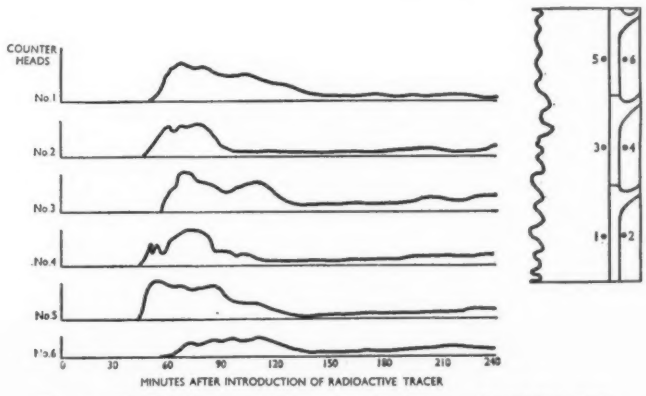


Fig. 6.—Distribution over outlet weir of primary sedimentation tank

proposed that instead of scraping continuously they should be used once every eight hours. Before a final decision could be made, however, the effect, if any, of the alteration on the solids removal had to be carefully examined.

Equal Distribution

This examination was to be carried out on the two halves of two of the pairs of tanks, one half of each pair being scraped continuously and the other intermittently. In order to ensure that any difference which might appear was in fact due to the method of operation it was necessary to establish that the distribution of sewage into the two halves of the tank was substantially equal.

Counter heads which had been previously carefully matched were installed in the exact centre of the centre outlet to each half of the tank and at precisely the same depth. The isotope was then tipped into the ingoing sewage just upstream of the inlet penstock and the activity appearing in the effluent was plotted.

As the curves show in Fig. 7, there was no significant difference between the two halves of the tank. Following chemical investigation of the ingoing sewage and of the effluents, intermittent scraping was adopted, with a great saving in wear and tear of the scraping gear.

Tests Extended

As a result of using intermittent scraping it was possible to extend the isotope experiments to an investigation of the pattern of flow of sewage along the whole length of the tank. The counter heads were suspended mid-stream of the sewage from wires stretched across the width of the tank at intervals of 20 ft, the first head being 10 ft from the downstream of the scumming weir and the last one 26 ft upstream from the outlet end. Tests were carried out at two rates of flow—10m.gal/day and 16m.gal/day and with the counter heads at varying depths—first at 2 ft below the surface of the sewage, then midway between the surface and bottom of the tank, and lastly 1 ft from the bottom of the tank.

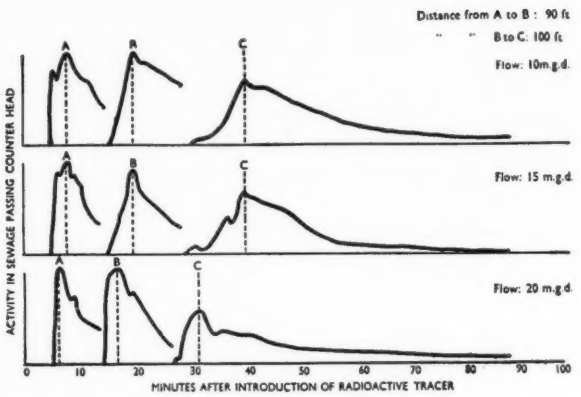


Fig. 8.—Velocity of sewage along floor of tank

Top Layers Stagnant

Results showed that at both rates of flow most of the activity which appears in the surface layers comes from upward diffusion and very little, if any, from horizontal flow, indicating that the upper layers are nearly stagnant. At the downstream end of the tank, however, the record of activity resembled more closely that in the lower layers, indicating that in this zone there was very considerable upward flow towards the outlet weir. There is no clear indication of any reflection from the end wall of the tank and the incorporation in the design of a trough weir to eliminate this seemed to Dr. Burgess and Mr. Green clearly justified.

Following the discovery that the flow of sewage is largely confined to the layers of the tank, the next tracer experiments were aimed at plotting the forward velocity of the sewage along the floor of the tank. Three counter heads were used and tests were run at rates of flow of 10, 15 and 20m.gal/day.

Passage of tracer past the first head (A) was plotted for 15 minutes and then the equipment was switched to the second counter head (B). Its passage past here was plotted for 11 minutes and the equipment was then switched to the third head (C) for the remainder of the time. Results are shown in Fig. 8.

Potential Obvious

From the overall results gained by Dr. Burgess and Mr. Green in their experiments at the Northern Outfall Works, it is clear that in the radioisotope the sewage engineer has a tool of great potentialities. It may be some time before these potentialities can be fully realized, since the interpretation of results is sometimes difficult. There is no doubt, however, that the use of radioisotopes enables information to be obtained which it would be otherwise impossible to secure.

This article is based on a paper, "The Use of Radioactive Isotopes for the Investigation of Sewage Treatment Plant" recently presented to the Institution of Civil Engineers by Dr. S. G. Burgess, scientific adviser to the LCC, and Mr. A. F. Green, principal scientific officer, LCC. They acknowledge the help given in compiling the paper to the Medical Officer of Health, Dr. J. A. Scott, and the Chief Engineer, Mr. J. Rawlinson, and to Mr. A. M. Allan and Mr. J. G. Paterson and others of their colleagues in LCC departments.

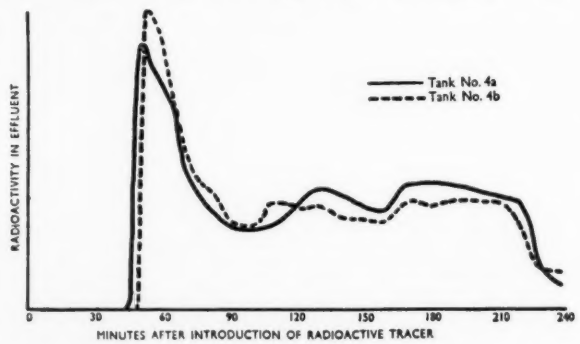


Fig. 7. — Comparison of sewage in two halves of primary sedimentation tank No. 4

NUCLEAR NEWS

- **C.E.G.B. Research Centre** *(This page)*
- **U.K.A.E.A. Reorganization** *(Page 274)*
- **U.S. Experts on N-Liability** *(Page 275)*

ONE million pounds will be spent on the research centre to be established by the Central Electricity Generating Board adjacent to the nuclear power station at Berkeley, Gloucestershire. The centre will consist of engineering, physics, metallurgy and chemistry laboratories, some of which will be specially constructed for studies in intensely radioactive materials. Laboratory accommodation for working with materials that are toxic but not radioactive will also be provided. One function of the centre will be the examination and testing of reactor construction materials taken from the Generating Board's operating power stations. Experimental work in nuclear and reactor physics will be carried out at the centre and it is hoped to devise nucleonic instruments to assist in the work of the laboratories and in reactor operation. About 200 scientists, engineers and skilled and unskilled tradesmen will be employed at the centre. It is expected that the centre will be functioning by the time Berkeley nuclear power station starts operating, some time in late 1960.

Winfrith Pipeline

WORK has begun on the construction of the pipeline which will take effluent from the Atomic Energy Establishment at Winfrith Heath, Dorset, into the sea at Arish Mell. This pipeline will run for five miles overland from Winfrith and for about a further two miles out to sea. The undersea route will follow the profile of the sea bed, except in a few places where a trench will have to be prepared by blasting through reefs and rock. Constructors-John Brown, Ltd., will be responsible for the first four miles of the overland pipeline from the site boundary and Taylor Woodrow Construction, Ltd., in association with Collins Submarine Pipelines, Ltd., for the remaining mile of overland pipeline and for the undersea section, which it is believed will be the longest underwater outfall to be constructed in this country.

Speaking at Stresa

AMONG the speakers at the conference on Industrial Prospects in Nuclear Energy to be held in Stresa, Italy, from May 11th to 14th, will be Sir Hugh Beaver, president of the Federation of British Industries, Sir Ralph Cochrane, who is in charge of nuclear research carried out by Rolls Royce, Ltd., Sir William Cook, Member for Development and Engineering of the UKAEA, Mr. D. E. H. Peirson, secretary of the UKAEA, Mr. A. J. Sayers, of the Nuclear Power Plant Co., Ltd., Mr. L. B. Shuffrey, of the English Electric Co., Ltd., and Dr. D. Taylor, of the Plessey Nucleonics, Ltd. The conference, which is being organized by the OEEC European Nuclear Energy Agency, will cover such subjects as the economics of nuclear power, the financing of nuclear power programmes, atomic law, the organization of consortia, and markets for nuclear materials and equipment.

I.A.E.A. Fellowships

TWELVE countries have already made some 200 fellowships and special training facilities available to the International Atomic Energy Agency in 1959, IAEA director general, Mr. Sterling Cole, recently announced. These facilities are in addition to the considerable number of fellowships which will be financed from the Agency's own Operating Fund. This Fund is built up from voluntary contributions received in cash from member countries and the target to be reached for fellowships and technical assistance was set at $1,100,000. Member states have shown considerable interest in this programme and during the first two months of 1959 ten governments sent about 100 applications for fellowships; ten other governments have announced their intention to send in the near future applications for about 200 fellowships. The Agency's training programme provides three major types of training: (i) short-term special training, for graduates from university or a technical school of university level or its equivalent; (ii) advanced and research training, for graduates from university or a technical school of university level or its equivalent and with previous experience in the field of nuclear science and technology.

U in New Guinea

A FOUNDATION for Geological Exploration in Netherlands New Guinea has been established by the Netherlands Government for the purpose of exploiting "minerals important for nuclear energy." A Bill will be submitted to the States General of New Guinea to provide freedom of operation for foreign nationals, as required by the European Economic Community treaty, but reserving the right of the government to refuse exploration licences and mining concessions to subjects who themselves practise discrimination.

N-Cargo from Norway

NORWAY may be able to commission her first nuclear propelled cargo-liner in 1970, says Dr. Emil Jansen, of the Institute for Atomic Energy, Kjeller. It all depends, of course, he continues, on whether the present development in the studies of the peaceful uses of nuclear energy continues.

Farmers' Reactor

IT has been announced at Wageningen in the Netherlands that a nuclear reactor will be erected there for the Institute for Application of Atomic Energy in Agriculture. It is believed this will be the first such reactor in Europe to be used for agricultural tests, and is expected to be ready in 1961. Special safety measures will render it possible to carry out research and experiments considered too dangerous in other agricultural research institutions. Mutation improvement and food preservation will be investigated.

Japan N-Plant Stage Further

Mr. Tamaki Ippon-matsu, vice-president of the Japan Atomic Power Company, is seen here talking to Mr. Arnold Lindley (*right*) assistant managing director of the General Electric Co., and Mr. R. N. Millar, director and general manager of GEC's Erith works, after his company had issued a letter of intent to GEC for the construction of a 150MW nuclear power station at Tokai-Mura, 70 miles from Tokyo

U.K.A.E.A. Changes

UNDER the recently announced changes in the organization of the United Kingdom Atomic Energy Authority, the Industrial Group has been divided into two: the Development and Engineering Group, and the Production Group. Sir William Cook, member for Engineering and Production, becomes head of the Development and Engineering Group with the title of Member for Development and Engineering. Sir Leonard Owen, managing director of the Industrial Group, becomes Member for Production (designate). The functions of Sir William's group will include the design, development and construction of reactors and associated plant (with the exception of certain development work, which will continue to be undertaken by the Research Group), engineering consultant work for the electricity boards, overseas organizations and consortia; and general engineering design and construction of all major building projects. The headquarters of the group will be at Risley, Lancashire. The Dounreay Experimental Reactor Establishment, the Culceth Laboratories, and research and development organizations at Capenhurst, Windscale and Springfields will come under its jurisdiction. The newly created Production Group will be responsible for the operation of the Authority factories (including the Calder Hall and Chapelcross reactors), research and development in aid of factory processes, and commercial activities of the existing Industrial Power Branch. The Group will include headquarters staff at Risley and plants at Capenhurst, Springfields, Windscale, Calder and Chapelcross.

EURATOM Report

A RAPID start on a joint experimental project with the United Kingdom is forecast by the Commission of the European Atomic Energy Community (Euratom) in its second general report recently published. Towards the middle of the year nuclear scientists from the Euratom countries will be working with British and other European experts on the construction of the DRAGON high-temperature, gas-cooled research reactor at Winfrith Heath. Euratom is to share the major part of the cost of this project with the United Kingdom (43.4 per cent. each, being a contribution of £4,340,000 each). This co-operation, says the report, is proof of the Euratom Commission's intention to give speedy effect to the agreement which it recently signed with the United Kingdom. The report underlines the importance which the Commission attaches to the rapid establishment of a Community Research Centre. It has decided against a completely new centre, as this would take too much time; it is currently considering whether some of those already in existence might be put, wholly or in part, at its disposal. In the meantime the Commission is actively pursuing a programme of research on heavy water reactors (which will include the construction by the Commission of a prototype reactor), material-testing reactors, and plutonium. Other important research work is to be undertaken by outside bodies for the Commission. The first contracts for this will deal with radiobiology, plutonium and controlled nuclear fusion. Negotiations for a common programme on the latter problem are in force with the French Atomic Energy Commission, and also the Max Planck Institute at Munich.

Shown at Hanover

AMONG exhibits on the UKAEA stand at the Hanover Fair in West Germany was a 10 kW light water moderated training research and isotope reactor designed and built by Vickers-Armstrongs, Ltd. Specially designed for installation in universities and research establishments, the reactor provides facilities for normal nuclear research, including bulk shielding experiments and cross-section measurements using a pile oscillator. Design flexibility enables potential users to indicate their special requirements in advance of fabrication and close collaboration at the detailed specification stage ensures provision of a facility tailored to individual needs.

B & W Booklet

ENGINEERS and others concerned with the development, application or erection of power, propulsion, and research reactors as well as nuclear components will be interested in a new bulletin issued by The Babcock & Wilcox Co., New York. Known as Bulletin AEB-8, the publication summarizes the company's activities in the nuclear field, ranging from the design and erection of complete reactors to the solution of design parameter problems. Copies of AEB-8 may be obtained from B & W, Atomic Energy Division, 161, East 42nd Street, New York 17, N.Y.

N-Station Sites Prepared . . . .

Work is progressing on clearing the site of the 500 MW nuclear power station to be built for the CEGB at Trawsfynydd, N. Wales. The lake alongside which the station will be built has been temporarily drained and earthmoving equipment is being used to clear and re-shape its bottom (*above*). An existing dam is being reinforced and the approach road to the station constructed (*left*)

Chapelcross Water

FARRANS, Ltd., the civil engineering contractors of Belfast, are to build a 500m. gallon reservoir for the Dumfriesshire County Council to meet additional demands for water supplies from the Chapelcross nuclear power/plutonium plant. The reservoir will be built on the Black Esk, near Kilburn, and will cost about £500,000. Construction of the reservoir will take about three years.

Show for 1960

THE INTERKAMA—International Congress and Exhibition for Instrumentation and Automation—which was such a resounding success in 1957, is to be repeated during 1960 from October 19th to 26th in Dusseldorf. The new INTERKAMA committee has already been formed and Dr. Eduard Gerecke, lecturing professor at the Zurich Technical College, elected as its chairman.

. . . . and Planned

The 175-acre site at Oldbury-on-Severn, Gloucestershire, where the CEGB want to build a 1,000 MW nuclear power station. Permission to build is being sought from the Minister of Power and the Local Planning Authority. The station would be the largest yet planned by the Board

N-Liability Report

APPROACHES aimed at achieving a solution of the international nuclear liability problem are the subject of a comprehensive report just published by the Atomic Industrial Forum, the national association of the U.S. atomic industry. Entitled " International problems of financial protection against nuclear risk," the report is based on a study conducted under the auspices of the Forum and the Harvard Law School. The problem to which the report is addressed arises " out of the risk, however slight, that damage of catastrophic proportions might occur abroad in the operation of atomic power facilities and related nuclear installations. This could impose a crushing loss both upon the public exposed to injury and also upon the enterprises operating or supplying the facilities, including American firms. The answer to the problem thus created involves devising means by which the risk of loss can be so allocated as to give reasonable protection to the exposed public while not obliging atomic enterprises to risk an intolerable burden of liability. " Ideally," the report continues, " a solution is called for which would embrace *all* nations participating in the development of nuclear power, and which would deal with all phases of the third party liability problem." The report recognizes that, as desirable as it might be, " a world-wide convention could not be negotiated until after many years of effort." The report notes, however, that, pending adoption of a global convention, a Western European convention now in preparation under the auspices of the Organization for European Economic Co-operation could " serve on an interim basis as a partial groundwork for further international arrangements and national legislation." The report strongly recommends government indemnification for damages exceeding the limit for which operators and suppliers would be held liable under the draft OEEC convention, and urges that this be provided for in advance rather than after the event. The Harvard study team suggests that an opportunity exists to work out a satisfactory solution to the third party liability problem under the joint nuclear power programme of the U.S. and the six countries of the Euratom community, all of whom are members of the OEEC.

New Firm's Work

ROLLS ROYCE and Associates, the company recently formed by Rolls-Royce, Ltd., Vickers, Ltd., and Foster Wheeler to undertake the development of nuclear marine projects, will work on the Dounreay land-based prototype submarine reactor, and will also be given responsibility for acting on Rolls Royce's behalf in the purchase from the United States of the propulsion unit for *Dreadnought*, Britain's first nuclear propelled submarine.

At the Milan Fair

SEVENTY square feet of the recently held 37th Milan Fair were taken up with exhibitions illustrating the industrial use of nuclear energy and its by-products. Britain, France, Canada, the United States and Italy were all represented in this section.

Graphite for Chapelcross

GRAPHITE for the moderators of the reactors at Chapelcross nuclear power/plutonium plant was supplied by British Acheson Electrodes Ltd. Graphite conforming to an exceptionally strict specification of purity was used. British Acheson have many years experience in the production of graphite for the British chemical, metallurgical and electronic industries. Their graphite is also used in the moderators of the Calder Hall reactors "A".

DEUCE for Liverpool

LIVERPOOL University has ordered the English Electric electronic digital computer, Deuce. It will be installed at the University's Ashton Hall Mathematical Laboratories in the early summer and will enable the laboratories to expand very considerably the services they offer both to university departments, such as the nuclear physics and oceanographic departments, and to outside organizations. Time on the computer will also be offered, as it becomes available, to local industry on a time-hire basis. A large part of the sum required to cover the cost of the installation has been raised by an appeal fund.

Book Reviews

Physics is Easy by D. S. Watt, BSc, MINA. Published by Princes Press, Ltd. Size: 8½ in. × 5 in. × 560 pp. Price £3 3s.

This book gives a complete survey of physics and is by the author of *Mathematics is Easy* which had such a phenomenal success as this author's first technical work. The book surveys from what physics means to you, to sputniks: in some 95 chapters and deals also with nuclear energy. It is profusely illustrated and gives many working diagrams by way of explanation. This is a useful work and we would recommend it to all who are interested in this field, and those who have studied the previous work *Mathematics is Easy* will find this an exceptionally interesting book.

Automatic Welding (translation from the Russian—*Avtomaticheskaya Svarka.*) Monthly. English translation available from British Welding Research Association. Price 10 gns. per annum.

This journal is a cover to cover translation of the monthly Russian journal *Avtomaticheskaya Svarka*, the organ of the Arc Welding Institute, Kiev, published by the Ukranian S.S.R. Academy of Sciences. The issue under review, for August, 1958, which is the first to be translated, is divided into three sections: (1) Scientific and Technical; (2) Industrial; and (3) News. The Scientific and Technical section is by far the longest and the papers included suggest that a wider field of interest is covered than might be inferred from the title. For instance, papers are included dealing with vacuum diffusion welding, production of ingots without feeder heads, metallography of aluminium welds, and impact strength of rail wagon doors. Other papers deal with the electrical characteristics of arcs and of arc welding equipment, and on the metallurgical, analytical and engineering aspects of welding. The Industrial and News sections give practical details on the welding of large aluminium vessels and the use of a specific type of welding generator respectively. It is difficult to see the reason for the two separate sections here. In general the papers are clear and concise, and detail the necessary experimental data which are so often missing. The conclusions are well summarized at the end of each paper. The translation is in general of excellent quality and a few unusual phrases may well be forgiven a translator who detects what is almost certainly an error in the original Russian (p. 94). It is a pity that the term " Candidate of Technical Sciences " is in general use in translation from the Russian as this may give the wrong impression—perhaps " Graduate of Technical Sciences " would be better.

F. G. Cox

ENGINEERING, MARINE WELDING and NUCLEAR ENERGY EXHIBITION

A Parting Look

Some of the exhibits not included in the preview published last month

A model to demonstrate the design and operation of the pumps supplied for the Chapelcross nuclear power-plutonium production plant was exhibited by **W. H. Allen Sons & Co., Ltd.** The Allen units installed at the plant consist of four 48/48 in. vertical double-suction centrifugal circulating water pumps each designed to deliver 50,000 gal of water/min against a total head of 67 ft when running at a speed of 490 rev/min. The model, having branches of 10/10 in., is designed for a duty of 2,000 gal/min, 67 ft head, at 2,450 rev/min.

Holland/SLM rotary compressors and vacuum pumps were shown by **The B.A. Holland Engineering Co., Ltd., (B5).** The representative models were side by side with a working 1 h.p. compressor, working both as compressor and vacuum pump, and a working sectional model which displayed the cellular compression effect carried out by the vanes. Rotary compressors of the vane type have the advantages of rotary motion, absence of pulsations and freedom from valves. The Holland/SLM rotary compressors enjoy the special advantage that, owing to the inclusion of floating rings which take the centrifugal thrust of the vanes, they are exceptionally free from wear. The passage of a molecule of gas through a Holland/SLM compressor is characterized by freedom from reversals of direction. It is a uniflow system in which a stream of gas is progressively compressed within a fixed stator by a revolving rotor in which the vanes are free to press outward up to a certain limit and no further. Lubrication is automatic and lubricant consumption small. Friction, either mechanical or gaseous, is the smallest for any machine made. The inlet and outlet ports are quite unrestricted in size and the flow is in every sense " streamlined."

Babcock and Wilcox Ltd., featured three displays illustrating their various activities in the nuclear energy field. Sectional models of a reactor group and of a steam raising unit for Hinkley Point nuclear power station were shown, together with a dramatic painting depicting Hinkley Point under construction. The second display referred to a variety of components for nuclear power generation and research, while the third display dealt with the company's collaboration with the Babcock and Wilcox Co., of America.

The Bridge Foundry Co., Ltd., (16OG), started operations in 1919 as a sand foundry and by 1933 had enlarged its interests to include a die foundry. From the beginning, castings for use in high pressure applications have been produced, and since that time there has been an ever increasing demand for castings for pneumatic and hydraulic equipment where complete soundness is essential. Where sand castings are concerned, both small and large quantities are produced and excellent service is given for prototype work. Castings of all weights up to a ton are produced. The company justly claim that its gravity die castings are second to none as far as soundness, finish and dimensional accuracy are concerned and rejections in hydraulic applications are below 3 per cent. In 1957 the Bridge Foundry Co., became a subsidiary of Clayton Dewandre Co., Ltd.

Exhibits on the **British Federal Welder & Machine Co., Ltd.,** stand concentrated on recent developments, particularly in the field of standard type resistance welding equipment, of which many new models were on show. In addition, many highly specialized tailor-made equipments were illustrated. These included some completely automized welding production lines with conveyor systems and hopper feeds, specially designed for high production outputs. A wide selection of the company's electronic control equipment was on show including control panels with special features for use in the welding field and control panels for general industrial purposes. In the field of automatic arc welding, several specially designed automatic machines were illustrated.

Among the exhibits shown by **The British Steam Specialties Ltd., (3J),** were a range of gunmetal and cast iron flanged and screwed valves, including ships' valves of various types. On show for the first time were the " Flumax " high lift bronze stainless steel fitted safety valve. " Vee-Reg " globe valves in bronze and steel, size range ¼ in. to 10 in., screwed and flanged, fitted with " V " ported stainless steel clack and seat, for use on high and low pressure saturated and super-heated steam, were also on show. A range of Velan steam traps, in all pressures up to 2,500 lb/sq.in. and temperatures up to 1,100° F., including the Velan Monofloat Steam Trap, designed for discharging condensate at steam temperature was displayed as well as a range of Velan forged steel and stainless steel bonnetless stop and gate valves.

Broom & Wade Ltd., (8H), were exhibiting " Broomwade " stationary air compressors and pneumatic tools. Among the stationary compressors was a new, two-stage, double-acting unit, Type L2000, delivering 2,200 cu.ft. of free air/min at 100 lb/sq.in. pressure. Speed 375 rev/min. This compressor is of unique design and incorporates several special features, notably the economy in floor space.

For over 30 years **Copes Regulators Ltd., (23OG),** have been concerned with boiler water level control problems for high and low pressure, land and marine boilers. They have in service several of the various types of regulators which were on show and are at present supplying over 100 regulators on special design for nuclear power stations in Great Britain. The marine 2-element regulator, as installed on the Royal Navy's Aircraft Carrier *H.M.S. Victorious* was also displayed.

On **Stand (3W), Deloro Stellite Ltd.,** demonstrated the task of hardfacing of pump shaft sleeves by spray-fusing. This is an advance on normal cold spraying because the " Stellite " powder deposit, with all its valuable heat, abrasion and corrosion resistant properties is actually welded on the base metal. Samples were available to take away for test purposes. Details and samples of the new Sprinkle-Fuse process were also available. This is the latest addition to Deloro Stellite's range of depositing processes. " Stellite " powder is placed on the component and subsequently fused by high frequency heating.

A scale model of the Hinkley Point nuclear power station was shown by the **English Electric Co., Ltd.,** who are building this station with Babcock and Wilcox Ltd., and Taylor Woodrow. Other exhibits by English Electric included diesel engines, fuel engine drilling rigs, switchboards and auxiliary motors.

Among exhibits shown by **Guyson Industrial Equipment Ltd., (61G),** were their range of light industrial shotblast machines; of particular interest being the latest model, SBP/41, sit-down shotblast cabinet. This is for day-long operation, a new development which brings the process of shot-blasting into line with production of large quantities of small parts such as valves and instrument parts requiring quick processing. Also on display were Hansen air and fluid line quick-connecting hose couplings. These couplings are leak-proof and have a ball-locking device which gives rapid smooth action and rugged wear. A wide variety of fittings is available for air, water, oil, gas etc., for 2-way shut-off, one way shut-off or straight-through flow.

Five divisions of **Imperial Chemical Industries Ltd.**—Billingham, Alkali, Heavy Organic Chemical, Dyestuffs and Metals—

and Marston Excelsior Ltd., an ICI subsidiary, were at the exhibition. On the nuclear side, the Metals Division showed samples of zirconium, titanium, niobium, and vanadium and also fuel cans and " Integron " extended surface boiler tubes. Marston Excelsior displayed burst cartridge detection gear and other products from their wide range of fabricated components for nuclear engineering.

Opperman Gears Ltd., displayed horizontal foot mounted geared motors from fractional to 60 h.p. and vertical flange mounted geared motors of up to 25 h.p. with single reduction worm gears, also co-axial speed reducers both helical and spur of up to 60 h.p. Single reduction worm type speed reducers of up to 120 h.p. and double reduction worm reducers of up to 120 h.p. and double reduction worm reducers with output torques of 100,000 lb/in. were also shown.

A model of a 100 MW turbo-generator designed for steam conditions applicable to nuclear power stations was shown by **C. A. Parsons & Co., Ltd.,** one of the member companies of the Nuclear Power Plant Co., Ltd. They also displayed an animated sectional model of a graphite-moderated gas-cooled reactor.

Various models from their large and varied range of liquid ring vacuum pumps and compressors were shown by **Ryaland (M/C) Ltd.** These pumps can handle any type of liquid, from the volatile to the highly viscous and at low and high temperatures and pressures. Most corrosive liquids can also be dealt with.

Versatility was the keynote of the stand occupied by the **Sperry Gyroscope Co., Ltd.** One of their exhibits was the " Introview " flow and corrosion detector which they manufacture under licence from ICI Ltd. This equipment uses eddy-current principles for the rapid detection of corrosion, thinning, flaws, and other abnormalities in non-ferrous materials and provides a permanent graphic record of the material being tested. Other exhibits included the Sperry fine position indicator for control rods in a nuclear reactor and a representation of a reactor control rod winding mechanism.

A display devoted to the fuel loading/unloading machinery for the Berkeley nuclear power station proved an immense draw. Arranged by **John Thompson Ltd.,** it included manufactured assemblies of the actual apparatus to be used, scale models and diagrammatic representations. Among the assemblies shown was the top 27 ft of the 50 ft high fuel chute handling machine. The purpose of this is to insert and leave a charge unit chute or guide in the reactor pressure vessel to enable uranium fuel elements to be passed in or out of the reactor core. Also displayed was the 4 ft diameter magazine which enables a load sufficient for one reactor fuel channel to be carried in the machine.

On view for the first time at the exhibition was a model of the new M6 type support hanger as will be used at Hinkley Point nuclear power station for supporting the CO_2 cooling circuit ducting. Designed by **Vokes (Genspring) Ltd.,** it is capable of supporting a load 90,000 lb over a vertical movement of 4 in. travel. Another new " M " type of support is the " M5 " which can support 45,000 lb.

The theme of the **Wakefield-Dick** stand was the comprehensive nature of this company's industrial and marine lubrication service. Particular emphasis was placed on the Wakefield-Dick contribution to the electrical generating industry and of special interest was their " Nucleol " range of radiation-resistant lubricants.

Nuclear Engineering Society

CHIEF engineers of the nuclear power consortia were among the guests at the annual dinner of the Nuclear Engineering Society held in Warrington, Lancs., recently. They heard both Sir Leonard Owen, Managing Director of the U.K. Atomic Energy Authority's Industrial Group, who is President of the Society, and Sir Donald Perrott, the Authority Member for Finance and Administration suggest that the future development of the nuclear power programme lay in careful programming of the Authority's work, increasing participation by industry and continuous examination of progress.

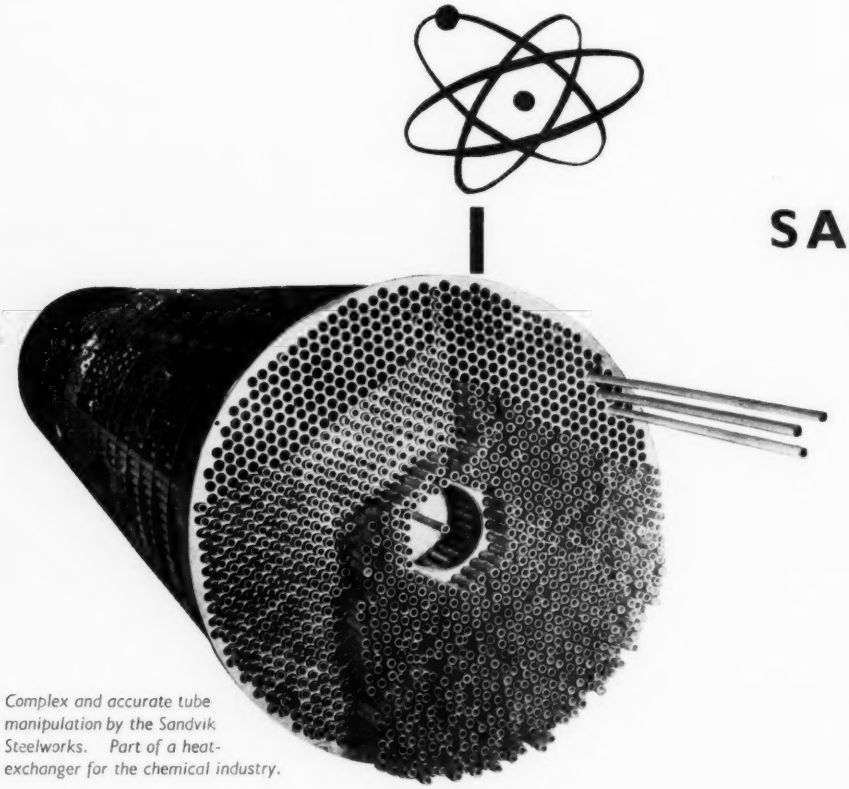
The Nuclear Engineering Society was formed soon after Risley embarked on its production work for the purpose of encouraging engineers within the Authority to keep in touch with all developments, to give younger engineers a forum for expressing themselves on all aspects of their work and to enable them to graduate into the old-established institutions. The Society has steadily grown in strength and there are now over 1,000 members in the branches at Risley, Windscale and Dounreay. It has now been extended to include members from branches of industry connected with nuclear energy. The chairman is Mr. J. L. Goudy, chief engineer (design industrial power) at Risley and the secretary, Mr. J. N. Cooper, of the production reactor design department, Risley.

Among the guests at the dinner were Sir Donald Perrott, Member of the Authority for Finance and Administration, Sir John Cockcroft, Member for Research, Dr. H. S. Arms (English Electric Atomic Power Group), Mr. J. W. Ashley (Atomic Power Constructions Ltd.,), Dr. K. J. Wootton (General Electric-Simon Carves Atomic Energy Group) and Mr. S. A. Ghalib (AEI-John Thompson Nuclear Energy Co., Ltd.). Mr. R. Vaughan, of the Nuclear Power Plant Co., Ltd., was unable to attend.

In proposing the toast of the Nuclear Engineering Society, Sir Donald Perrott said he would challenge most of them to have predicted Britain's present position, when they first started their work. He could in fact remember Sir John Cockcroft returning from Canada and warning the Government that the development of nuclear energy would be expensive and that the Harwell establishment alone might have to increase its staff to over 600 people within ten years. In fact, the manpower of the Authority had gone from 18,000 to 35,000 in the five years since the Authority was formed. They were clearly facing quite a problem of expansion. There was no doubt that the rate of increase would have to be controlled and thought given as to how much could be put out to industry.

On the other hand they had an immense amount of talent amongst the younger men and the Authority's function and intention was to encourage these young men to the utmost. He paid tribute to the interest and enthusiasm of the scientists and engineers and to the part which the Society played in helping to make the most of their talents, and assured them of the Authority's support in their work. Sir Leonard Owen, replying, reviewed the Industrial Group's work during the past year, which included putting spade to ground for the first truly prototype reactor, starting up the first part of the new Springfields extensions, handing over all four Calder Hall reactors and starting up the first reactor at Chapelcross. They had got to the point where a start could be made on the site of the Windscale chemical plant and had started up the materials testing reactor at Dounreay. It had been a year of technological achievement.

In addition to this, the national power programme was well on its way and he thought the consortia had something here to be proud of. Now, both the Authority and the consortia had got to concentrate their efforts on bringing down costs and he believed they could do it. The main problems for the future were: the necessity for increasing burnup of fuel and bringing down processing costs; the achievement of higher rating and reduction of capital costs: higher steam temperatures; finding out how to burn plutonium safely and economically and lastly, to get to the point at which siting and safety were no longer such overriding factors. All these problems were being attacked and only by doing it would they keep ahead of their competitors. He looked forward to a controlled expansion of the Industrial Group at a reasonable and manageable rate. Their work would need careful programming and they should bring in industry and the consortia. There should also be a continuous examination of progress to get the most out of it. Ahead of them lay even more difficult problems than they had faced in the past.



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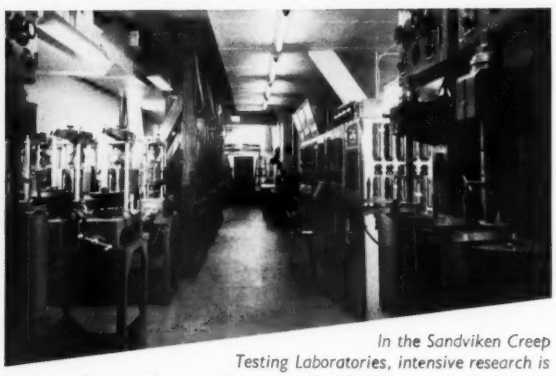

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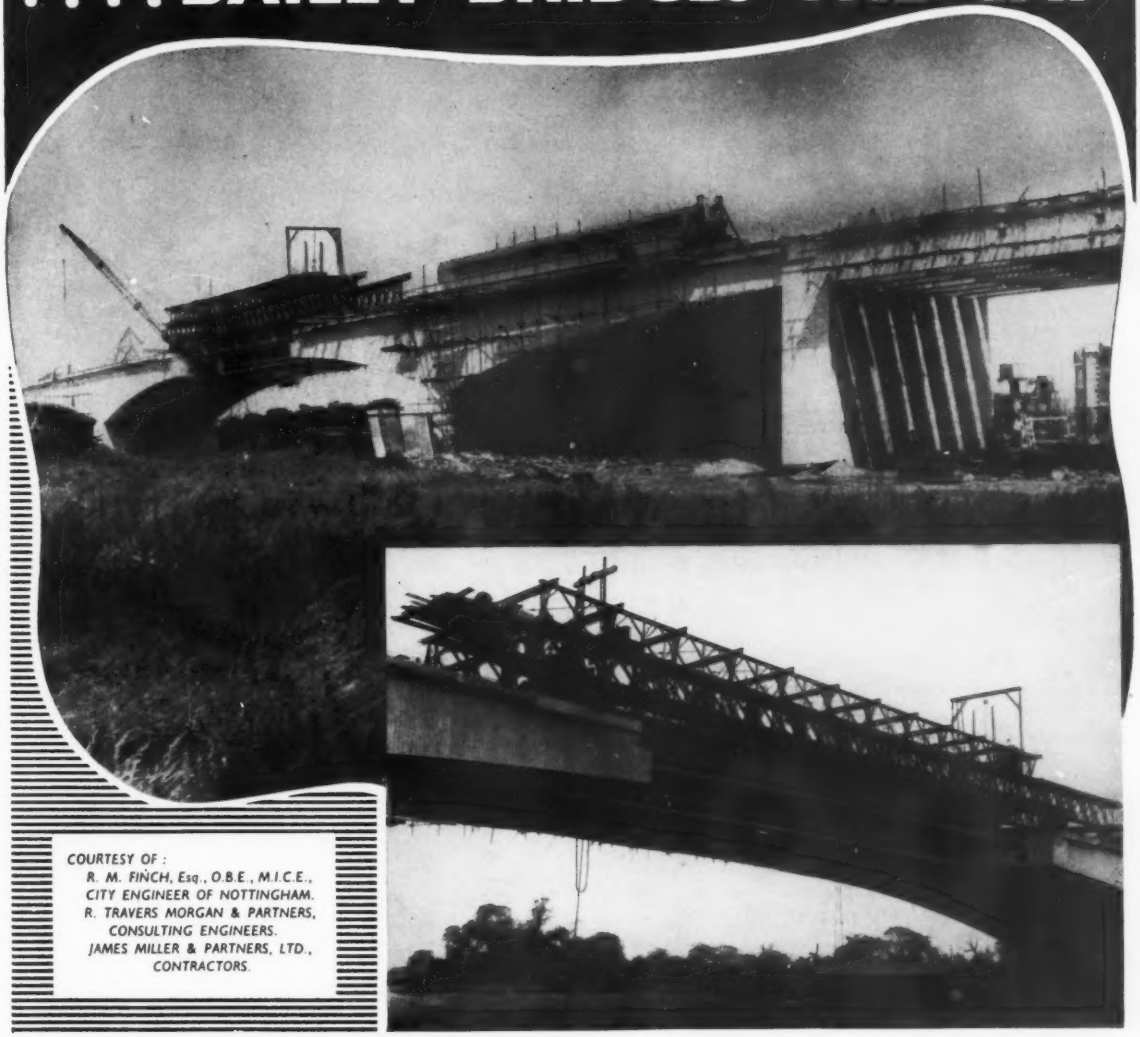

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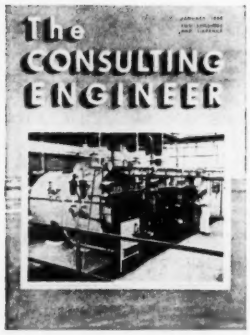

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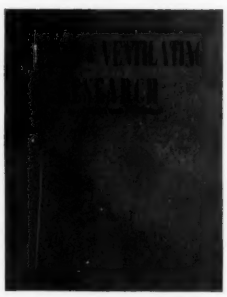

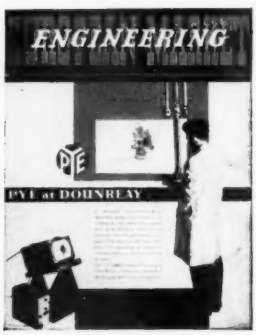

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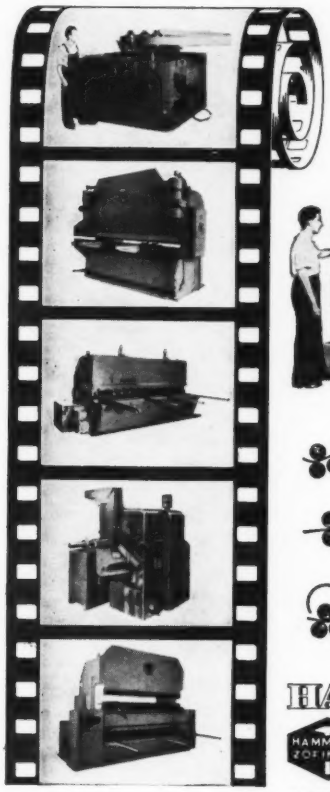

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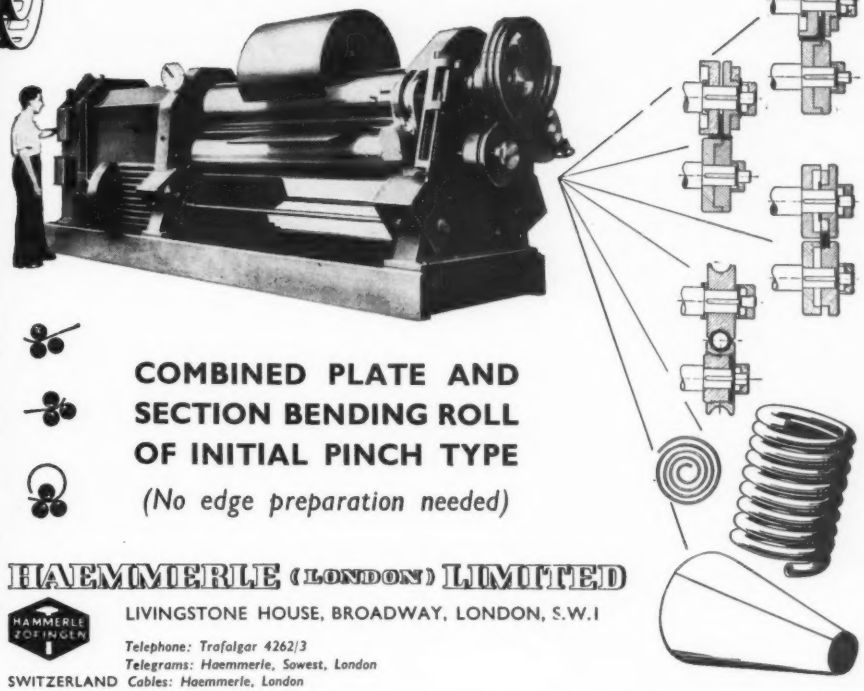

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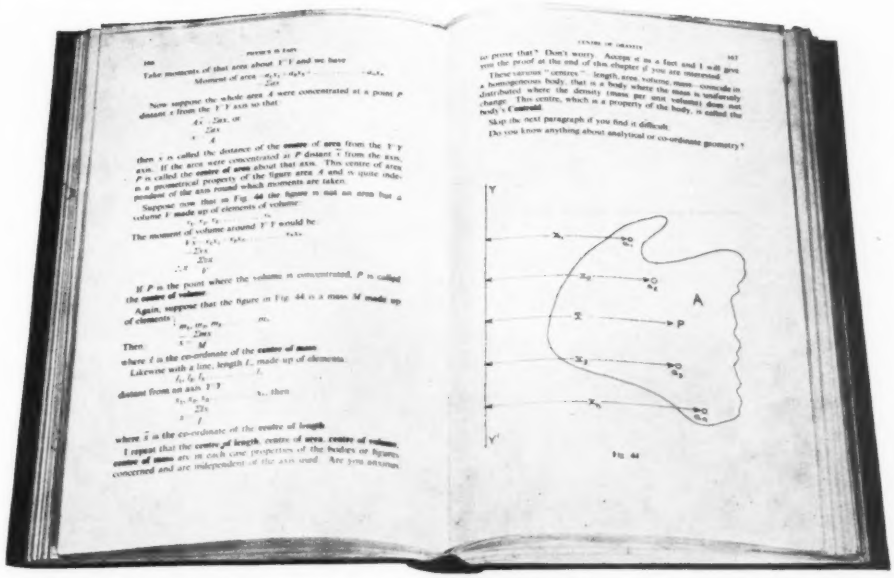

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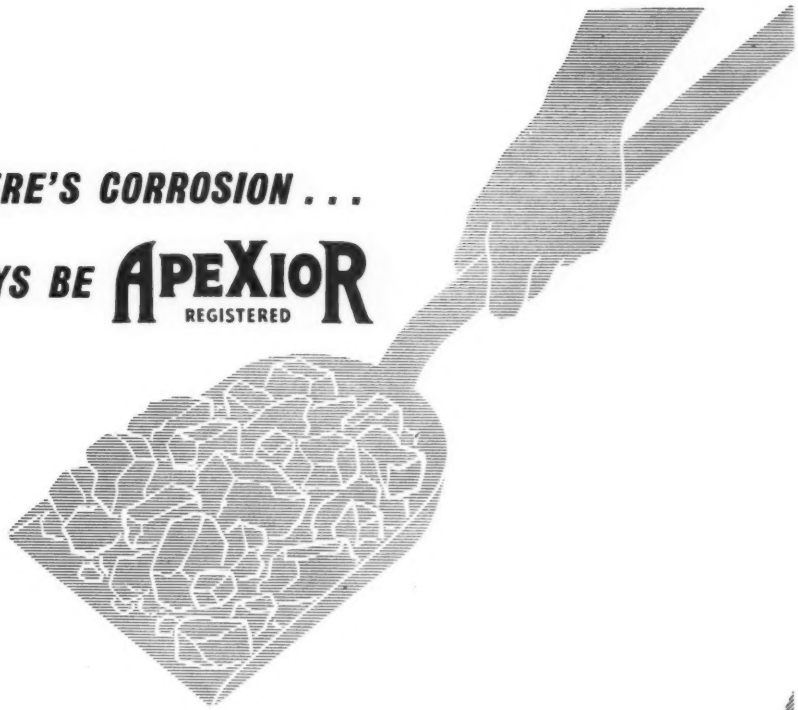

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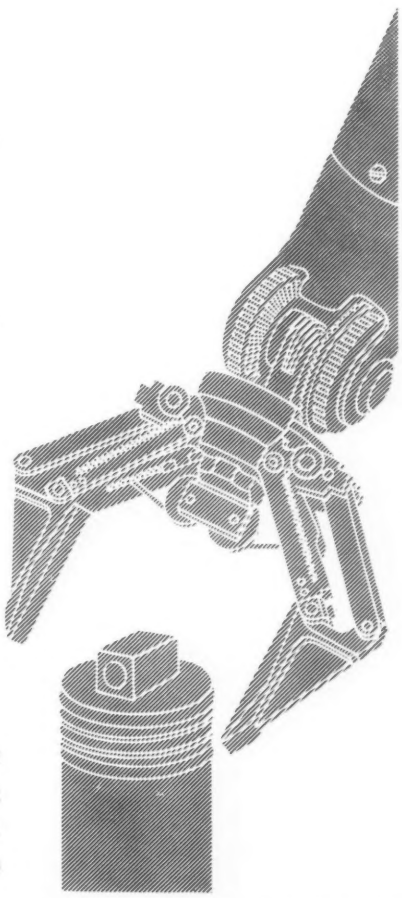

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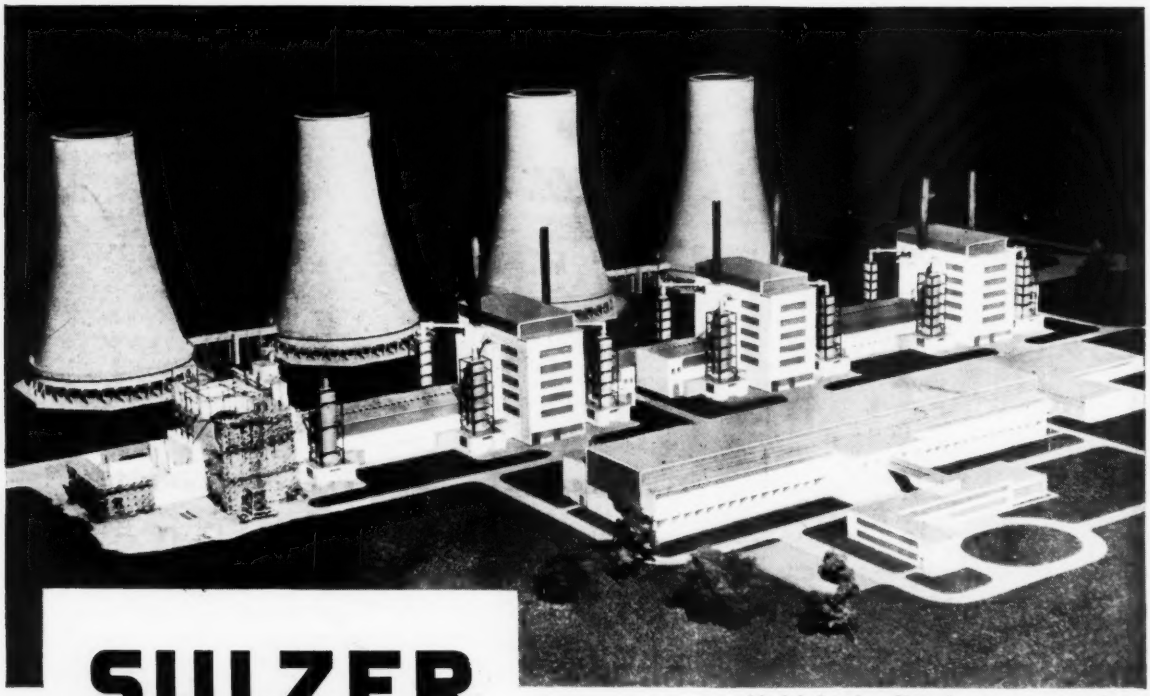

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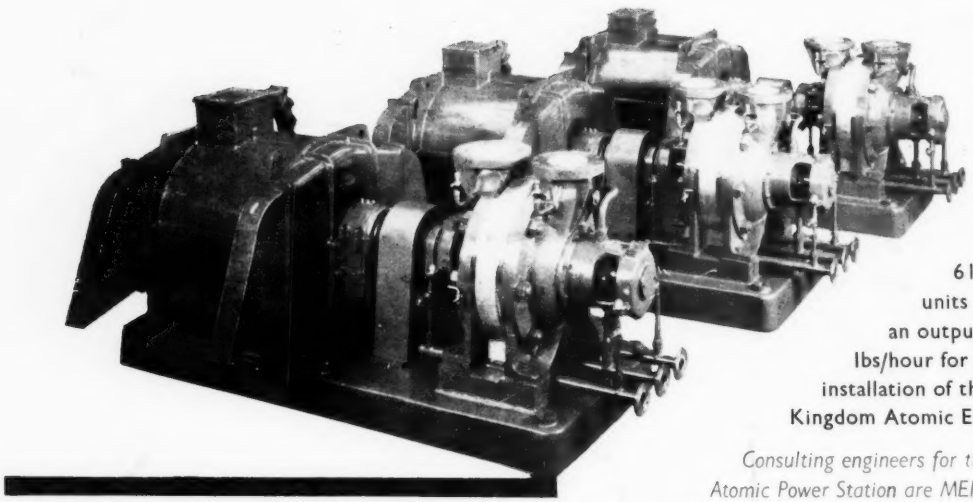

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